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(NASA-CR-160487) RESULTS OF TESTS USING A 0.03-SCALE MODEL (47-OTS) OF THE SPACE SHUTTLE INTEGRATED VEHICLE IN THE NASA/AMES RESEARCH CENTER 9 X 7 FOOT SUPERSONIC WIND TUNNEL (IA184), VOLUME 2 (Chrysler Corp.) 00/16

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VOLUME 2 OF 2

RESULTS OF TESTS USING A 0.03-SCALE MODEL (47-OTS) OF THE SPACE SHUTTLE INTEGRATED VEHICLE IN THE NASA/AMES RESEARCH CENTER 9 X 7 FOOT SUPERSONIC WIND TUNNEL (IA184)

by

J. J. Daileda

Rockwell International Space Systems Group

Prepared under NASA Contract Number NAS9-13247

by

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New Orleans, La. 70189

for

Engineering Analysis Division

Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas

WIND TUNNEL SPECIFICS:

Test Number: ARC97SWTA347
NASA Series Number: IA184
Model Number: 47-OTS
Test Dates: April 6, 1979 through April 13, 1979
Occupancy Hours: 33

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Chrysler Huntsville Electronics Division/Slidell Engineering Office assumes no responsibility for the data presented other than display characteristics.

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ABSTRACT

An experimental investigation (IA184) was conducted in the NASA/Ames Research Center Unitary Plan Wind Tunnel 9 x 7 foot supersonic leg from April 6 through 13, 1979. This test was a continuation of test IA105B which ran from January 24, 1978 until terminated on February 2, 1978 due to a problem with the UPWT main drive system.

The objectives of the test were to obtain: distributed pressure data on each vehicle element and component as affected by elevon deflection; wing load indicator data; orbiter force and moment data; elevon hinge moments; and four component vertical tail force data. A secondary objective of the test was to obtain pressure data on a simulated ascent air data system probe mounted in the nose of the external tank.

Data were obtained at Mach numbers of 1.55, 1.8, 2.2 and 2.5 at a Reynolds number per foot of 3.5×10^6. Data were obtained by making angle-of-attack sweeps at a series of constant angles-of-sideslip. The range of angles-of-attack and sideslip was between ± 6 degrees.

ABSTRACT (Concluded)

Configuration variations consisted of a series of differential inboard/outboard elevon angle settings at zero aileron angle, with and without the Shuttle Infrared Leeside Temperature Sensing (SILTS) pod on the orbiter.

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IB-ELV = 4, ØB-ELV = -7, MACH = 1.8, AADS = 90, SILTS ON

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INTRODUCTION

The 0.03-scale model (47-OTS) of the space shuttle integrated vehicle was tested in the NASA/Ames Unitary Plan Wind Tunnel 9 x 7-foot supersonic leg between April 6 and 13, 1979. This test, designated IA184, used a total of 33 test hours in the facility. Test IA184 was a continuation of test IA105B which ran in the same facility from January 24, 1978 until it was terminated on February 2, 1978 due to a problem with the UPWT main drive system.

Data were obtained at Mach numbers of 1.55, 1.8, 2.2 and 2.5 at a Reynolds number per foot of 3.5×10^6. Angle-of-attack sweeps were run at constant angles-of-sideslip over a range of angles-of-attack and sideslip between ± 6 degrees.

Configuration variations consisted of a series of differential inboard/outboard elevon angle setting at zero aileron angle, with and without the Shuttle Infrared Leeside Temperature Sensing (SILTS) pod on the orbiter.

The model was instrumented with a total of 762 pressure taps distributed as follows: 443 on the orbiter, 181 on the external tank, and 138 on the solid rocket booster. Orbiter forces and moments were measured by a six-component strain gauge balance. Wing torsion, bending and shear were measured using a three-component balance (gauged wing-mounting beam) on the right side of the model. The right elevons were each mounted on a strain-gauged beam to measure hinge moments. Both "pressure" and "force" vertical tails were used during the test. The

INTRODUCTION (Continued)

"force" vertical had a dummy balance gauged to measure shear, bending, torsion and the pitching moment of the vertical tail.

This report provides a description of the test consisting of remarks on the conduct of the test, descriptions of the model and the test facility, details on test procedure, information on data reduction, and both plotted and tabulated test results.

This report consists of 1 volume of plotted pressure data and tabulated force data; and 1 volume of tabulated pressure data on microfiche. The volumes are arranged in the following manner:

VOL. NO.	CONTENTS	MICROFICHE PAGE NO.
1	IA184 Plotted Pressure Data	-
1	IA184 Force Data Tabulations	-
2	IA184 Tabulated Pressure Data Orbiter Fuselage (B) D/S 01-21	1-6
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NOMENCLATURE

SYMBOL		DEFINITION
A_i	-	Area over which P_i acts, ft^2.
B_{vt}	-	Vertical tail bending moment, in-lbs.
B_w	-	Wing bending moment, in-lbs.
C_{A_b}	CAB	Orbiter base axial force coefficient.
C_{A_f}	CAF	Orbiter forebody axial force coefficient.
C_{A_u}	CAU	Orbiter axial force coefficient, uncorrected.
C_{B_v}	CBV	Vertical tail bending moment coefficient.
C_{B_w}	CBW	Wing bending moment coefficient.
Ch_{e_i}	CHEI	Inner elevon hinge moment coefficient, about hinge line X = 1387.0.
Ch_{e_o}	CHEØ	Outer elevon hinge moment coefficient, about hinge line X = 1387.0.
C_ℓ	CBL	Orbiter rolling moment coefficient, body axis system.
C_{m_B}	CLMB	Orbiter base pitching moment coefficient.
C_{m_f}	CLMF	Orbiter forebody pitching moment coefficient.
C_{m_u}	CLMU	Orbiter pitching moment coefficient, uncorrected
C_n	CYN	Orbiter yawing moment coefficient.
C_{n_v}	CTV	Vertical tail yawing moment coefficient, using vertical tail reference.
C_{N_B}	CNB	Orbiter base normal force coefficient.
C_{N_f}	CNF	Orbiter forebody normal force coefficient.
C_{N_u}	CNU	Orbiter normal force coefficient, uncorrected

NOMENCLATURE (Continued)

SYMBOL		DEFINITION
C_{N_W}	CNW	Wing normal force (shear) coefficient.
C_{p_i}	CP(i)	Surface tap pressure coefficient, port i.
C_{S_V}	CSV	Vertical tail shear force coefficient using vertical references.
C_{T_W}	CTW	Wing torsion moment coefficient.
C_Y	CY	Orbiter side force coefficient.
H_{e_i}	-	Inboard elevon hinge moment, in-lbs.
H_{e_o}	-	Outboard elevon hinge moment, in-lbs.
M	MACH	Freestream Mach number.
N_{vt}	-	Vertical tail normal (shear) force, lbs.
N_W	-	Wing normal (shear) force, lbs.
P_i	-	Pressure at surface tap i, psf.
P_o	P	Freestream static pressure, psf.
P_t	PT	Freestream total pressure, psf.
q	Q(PSF)	Freestream dynamic pressure, psf.
	RN/L	Unit Reynolds number, million per foot
T_t	TTF	Freestream total temperature, ^{o}R.
T_{vt}	-	Vertical tail torsion moment, in-lbs.
T_W	-	Wing torsion moment, in-lbs.
α	ALPHAT	Angle-of-attack of the ET/SRB's, degrees.
α_O	ALPHAØ	Orbiter angle-of-attack, degrees.
β	BETAT	Angle-of-sideslip of the ET/SRB's, degrees
β_O	BETAØ	Orbiter angle-of-sideslip, degrees.

SYMBOL		DEFINITION
δ_{e_i}	ELVRI	Right inboard elevon deflection, under air load, degrees.
δ_{e_o}	ELVRØ	Right outboard elevon deflection, under air load, degrees.
$\delta_{e_i}/^{no}_{load}$	ERI/ELI	Inboard elevon deflection, degrees preset (Right/Left).
$\delta_{e_o}/^{no}_{load}$	ERØ/ELØ	Outboard elevon deflection, degrees preset (Right/Left).
$\Delta\delta_{e_\emptyset}$	DØ	Elevon increment due to air load, ELVRØ-ERO.
$\Delta\delta_{e_I}$	DI	Elevon increment due to airload, ELVRI-ERI.
	IB-ELV	Nominal inboard elevon setting - deg.
	ØB-ELV	Nominal outboard elevon setting - deg.
$\emptyset$	PHI	Angular cylindrical coordinate position around body - deg.
X/C_{BF}	X/CBF	Chordwise location on body flap, fraction of local chord.
X_o/L_o	X/LB	Longitudinal location on orbiter body surface, fraction of body length.
X_s/L_s	XS/LS	Longitudinal location on solid rocket booster body surface, fraction of body length.
X_T/L_T	XT/LT	Longitudinal location on external tank body surface, fraction of body length.
X_v/C_v	XV/CV	Chordwise location on vertical tail, fraction of local chord.
X_w/C_w	XW/CW	Chordwise location on wing surface, fraction of local chord.
Y_o	YO	Orbiter base lateral centerline.

NOMENCLATURE (Concluded)

SYMBOL		DEFINITION
η_{BF}	Y/BBF	Spanwise location on body flap, fraction of body flap span.
η_v	ZB/BV	Spanwise location on vertical tail, fraction of vertical tail span
η_w	Y/BW	Spanwise location on wing, fraction of semi-span
	AADS	Parametric value of rotation angle for AADS probes.
	GAPS	Parametric value of 1.0 indicates wing gaps sealed.
	SILTS	Parametric value - 1.0 indicates SILTS on and 0.0 indicates SILTS off.
X_{CP_v}	XCPV	Vertical tail center-of-pressure, longitudinal location, in.
X_{CP_w}	XCPW	Wing center-of-pressure, longitudinal location, in.
Y_{CP_v}	YCPV	Vertical tail center-of-pressure, lateral location, in.
Y_{CP_w}	YCPW	Wing center-of-pressure, lateral location, in.

REMARKS

Test IA184 was conducted basically as planned during the period between April 6 and April 13, 1979. The model was installed in the tunnel during the week of March 19, however, a variety of computer and equipment problems delayed the test start date. All objectives of the test were accomplished.

The test was conducted as planned except as follows:

1. The pressure instrumented tail was removed and the force instrumented vertical installed prior to the completion of Configuration 17 rather than after. Therefore, runs 53, 55 and 56 are repeats of runs 48, 49, and 50, respectively, with the only change being the vertical tail.

2. There was no plan to run the "force" vertical with SILTS pod installed. However, this configuration was tested during runs 53 through 79.

3. Runs 104 through 109 repeat runs 93, 95, 97, 98, 100 and 102 with tape covering all metric gaps (except for the main balance). These runs were made to again determine the effects of the metric gap on the orbiter aerodynamic simulation.

During the test various events occurred having a possible effect on the test results. These items are listed below.

1. Pressure tap 688 had a slow leak for the entire test. It was moved from Scanivalve A-2, Port 12 to Scanivalve B-15, Port 29 prior to the test.

2. Pressure taps 573 through 576, on the top of the vertical tail, were measured on runs 4 through 50. These taps were connected to Scanivalve B-13, Ports 25 through 28, respectively.

3. Pressure taps 291 through 297 were added to the orbiter prior to the test. These taps are located as follows:

REMARKS (Concluded)

TAP NO.	X_o	Y_o	Z_o	ϕ
291	1317.5	-106.6	363.5	71.1
292	1317.5	-106.8	402.0	91.1
293	1390.0	-113.4	334.3	59.9
294	1430.2	-117.5	334.6	60.9
295	1454.5	-118.9	360.5	71.6
296	1454.5	-117.0	402.6	91.3
297	1480.1	-122.7	332.9	61.3

4. During runs 20 through 24 no data were obtained from Scanivalve A-1 (see Reference 1 for affected pressure tap numbers).

5. Prior to run 43 the simulated GH_2 pressure line on the external tank was broken off aft of station X_T 1700 (full scale). This protuberance was missing during runs 43 through 50, after which it was repaired.

6. During runs 53 through 79 pressure taps 1392 and 1507 were plugged.

7. During runs 53 through 115 all vertical tail pressure taps (5xx numbers) were disconnected (force vertical tail was installed).

8. During runs 93 through 109, pressure tap 858 was plugged and 857 and 887 were leaking.

9. During runs 104 through 109 the following pressure taps were plugged: 182, 401, 409, 417, 425, 433 and 685.

10. Check loading of the wing (right hand) in the tunnel revealed that the wing fouled against the orbiter for negative values of torsion greater than 500 inch-pounds.

CONFIGURATIONS INVESTIGATED

The model for the NASA/Ames 9 x 7-foot tunnel test period was a 0.03-scale replica of the Rockwell International Space Shuttle Vehicle in launch configuration. The launch configuration consists of the assembly of a payload carrying orbiter, an expendable external oxygen/hydrogen tank (ET)(which provides fuel for the orbiter main engines), and two expendable solid rocket boosters (SRB's). The general layout of the model is shown in Figure 2a.

The orbiter is of blended wing body design with a double delta planform ($81^{\circ}/45^{\circ}$ leading edge) 12% thick wing with full span elevons incorporating a six-inch interpanel gap between the independently deflectable inboard and outboard panels. A single swept (45°) centerline vertical tail with rudder and/or speed brake capability is mounted between two orbital maneuvering system (OMS) pods, and a single body flap (to aid in trim control while the speed brake is flared during re-entry) is fitted on the lower trailing edge of the fuselage.

The orbiter fuselage is in accord with Rockwell International control drawing VL70-000140A, with the vertical tail as defined by drawing VL70-000146A. The OMS pods are of the later VL70-000140C configuration, these being a combination of the VL70-08401 and VL70-08410 drawings. Fitted to this is a new orbiter vehicle 102 wing as defined in the MD-V70 data book(s). For the purposes of this test and report, this combination shall be referred to as a "102 orbiter" with the concurrence of the Aerodynamics Loads Group. The orbiter is shown in

Figure 2b.

The ET is of cylindrical cross section with a nominal diameter of 333.0 inches full-scale and a maximum diameter of 336.2 inches full-scale. The forward portion of the ET has a tangent ogive nose which terminates in a biconic nose cap over the LOX vent valve. The biconic nose has a pitot and two static pressure taps as a sensing part of the ascent air data system (AADS). The forward third of the tank is filled with LOX, and the aft two thirds is a vessel for liquid hydrogen. The aft end of the tank is basically an ellipsoid of revolution. Between the two vessels is a structure of stiffeners which is slightly larger than the nominal tank diameter. Covering the entire tank is a spray on foam insulation (SOFI) of varying thickness as dictated by the relative heat load, i.e., approximately 2.5 inches thick on the tangent ogive, 1.0 inch thick on the cylindrical portion of the tank and 2.0 inch thick on the rear ellipsoid. The diameters given above include this SOFI. Standing proud of this insulation are a number of external protuberances which fall into three major categories: electrical trays, fluid lines, and attach hardware. Electrical trays which run parallel to the center-line of the tank are simulated, those which run up next to the aft orbiter/ET attach hardware are not. Fluid lines modeled are the LOX and LH_2 feed and vent plumbing. The attach hardware that is considered as part of the tank is the front and rear ET/orbiter attach structure, which is discarded with the ET at the end of the main engine burn.

The external tank is built to the geometry described above and more specifically to Rockwell International Interface Control Drawing ICD 2-00001, Rev. C, plus Interface Revision Notices B and C. The external tank is shown in Figure 2c.

The two solid rocket boosters (SRB's) are 146-inch nominal diameter cylinders, each with an 18-degree semi-angle nose with a 13.27-inch spherical tip. An 18-degree flared skirt, 208.20-inch diameter, protects the gimbaled rocket nozzle. A flexible, donut-shaped seal and thermal shield is provided between skirt and nozzle. Major protrusions from the basic envelope include a forward attach lug, separation thrusters front and rear, aft attach ring, various stiffeners and a full length electrical systems tunnel.

In common with the external tank, the SRB is built in accord with the Rockwell International Interface Control Document ICD 2-00001C, with the supplement of Interface Revision Notices B and C. An SRB is shown in Figure 2d.

The entire model was therefore basically in accord with the Configuration 6 Launch Vehicle, comprised of the 102 orbiter and T_{39} tank and S_{27} boosters.

The orbiter provided for this test series is constructed utilizing existing orbiter fuselage, vertical tail, OMS pods wing, and body flap components. An internal beam/bridge/balance block has been constructed to allow mounting the orbiter from the attach hardware of the ET and to measure six component airloads on the orbiter. Safety factors of three (3) on yield and five (5) on ultimate have been observed. The complete orbiter weighs approximately 140 pounds. The model has been principally fabricated of 17-4 stainless steel and aluminum alloy with some contouring with Renite. The orbiter is fabricated around a control balance block of 17-4 bored and sleeved to accept the Task 2.5-inch MK XXII balance. This block is located in the rear half of the fuselage and the 7076 aluminum pieces which form the outer mold line of the fuselage are bolted to it. These pieces consist of a fuselage cover, two fuselage fairings and two wing fairings at the rear of the body, two side covers, and a forward nose and top cover. The two OMS pods are fabricated of 7076-T6 aluminum alloy and are secured to the aft top cover with 10-32 AHCS. The OMS nozzles are simulated in aluminum as are the RCS thrusters. The fuselage and OMS pods are heavily pressure instrumented.

The wing is a two piece aluminum article screwed to a central stainless steel wing beam. This beam of cross shaped planform supports one wing on a tang on each side of the central plate. The right hand tang is instrumented with strain gauges to form the three component wing load indicator balance. While the center of this beam forms the outer mold line of the bottom of the orbiter, the tangs are of course, out of the airstream. The wings are made integral with the glove and a labyrinth seal is provided on the metric side to improve the data quality. The wings are extensively hollowed to reduce the model weight. The left hand wing is instrumented with pressure taps. Each of the wings is fitted with deflectable inboard and outboard elevons which are supported in torsion only by a beam mounted on the hinge line, and in all other degrees of freedom by plain bearing hinges, also on the scale hinge line. Identical R.H. and L.H. elevon supports insure similar aeroelastic deflections. The opposite end of the elevon support beam is fitted with a ball bearing to minimize hysteresis effects. The right hand wing panels are supported on beams which are strain gauges. Available deflections are listed in Table III. For negative elevon deflections (T.E. up) simulated flipper doors are fitted to the upper wing surface.

An aluminum body flap with hinge moment capability and 40 pressure taps is provided. The panel is mounted with a single component Armco beam pinned to an Armco shaft and bracket. This bracket is attached to the ball bearing mounted Armco hinge shafts which support the panel in torsion. The remainder of the loads are carried on the hinges. The opposite, orbiter end of the flexture is supported in an Armco cavity through a single ball bearing to minimize hysteresis effects. Four pairs of holes between the body flap bracket and the hinge shaft allow for selection of one of the four of settings, -11.7, 0, +16.3 or +22.5 degrees. The hinge moment capability was not used, nor was the body flap deflection changed during this test entry.

Two vertical tails are provided for this test, the first being of 17-4PH Armco with a single plain hinged rudder/speed brake on each side.

These panels are individually pinned to the hinge shaft, the shaft is then pinned to the vertical. Five sets of hole pairs are provided between the panels and the shaft to provide speed brake settings. The entire shaft is then rotated and pinned to provide one of five rudder deflections; thus any combination of rudder/speed brake provided can be run. No rudder/speed brake deflections were used for this test. This is a pressure instrumented surface with 76 pressures (including one of the base group, #301). The hardline tubulations terminate at the front of the base of the tail, from whence the tubes are of flexible plastic to the Scanivalves. The tail itself is hard mounted to the balance block with six AHCS in a cavity at the upper rear of the fuselage.

The second vertical is of aluminum and mounts through this same cavity, but is supported on a balance to measure vertical tail airloads directly. The upper and lower halves of the left and right panels of the rudder are all separately hinged on ball bearings, with single flexure strain gauge beams supporting each panel in torsion about the hinge line. Panel deflections are set by changing brackets which are screwed to the rudder and pinned and screwed with 6-40 AHCS to the strain gauge beam. Again, the inner end of the steel beam is mounted in a steel pocket insert via a ball bearing to minimize hysteresis. This arrangement allows certain discreet δ_r/δ_{sb} combinations only. The speed brake and rudder deflections remained at zero and rudder hinge moments were not measured during this test.

Simulated SSME nozzles are provided in the base of the orbiter, since no sting interferes. The nozzles are set at the nominal angles of 16 degrees up, no yaw upper, and 10 degrees up, ±3 1/2 degrees yaw outboard for the lower two. The material used is aluminum alloy. The nozzles are mounted to a base plate which closes off the balance cavity at the back of the orbiter.

The entire orbiter is mounted on the balance mentioned, with the taper fitting into a block in the cavity at the rear of the fuselage mentioned above. This block is screwed to a beam running under the balance block and also to a stiffener rod that runs forward above the right corner of the balance block to a "flying wedge" piece attached to the right front of the longitudinal beam. The ET attach hardware mounts to the bottom beam through holes in the bottom of the orbiter.

The external tank is principally fabricated of aluminum alloy to reduce weight and fabrication costs. The approximate weight of the external tank with instrumentation is 190 pounds. Safety factors of three (3) on yield and five (5) on ultimate have been observed in the design and construction of the tank.

The 333-inch full-scale diameter tank is built up out of four principal shell-like pieces that conform to the outer mold line of the tank including the spray on foam insulation. These pieces are a nose which includes the entire tangent ogive (and is actually made up of two non-separable pieces because of a late lines change), a cylindrical mid-body, a short cylindrical aft body, and an aft cap. Slipped around the back of the aft body to fair into the cap is a ring designated a recontouring block, and an .030-inch shim is placed beneath the cap. These last two items are also the result of a late lines change.

The nose is secured to the mid-body with 1/4-20 AHCS, and the joint from the mid to aft body is secured with 10-32 AHCS. The recontouring block is secured with 10-24 AHCS and the cap is fastened to the aft body with 1/4-20 AHCS. There are two holes aft and one hole forward on each side which are spotfaced inside and out to accept the SRB ring mounting studs and screws.

Slipped into the front of the nose of the tank is a biconic vent valve housing with an integral 10-degree half-angle conical yaw probe at the front. This yaw probe (The Ascent Air Data System or AADS) is instrumented to scale with two .010-inch OD hypodermic tubing taps at the scale location, .075-inch aft of the tip of the spike (taps 1901 and 1902).

The orbiter/ET attach hardware is scaled to as great a degree possible and is load bearing. The orbiter/ET front attach was originally fabricated from a single piece of 17-4 stainless steel with two end plates, but prior to testing was modified to prevent orbiter rolling moment from being transmitted to the structure by use of a pin joint at the orbiter. The lower end plate fits into a milled recess in the ET mid-body and is secured with 10-32 AHCS; the upper one fitting into an analagous recess in the orbiter, and using 5/16-24 AHCS to fasten it to the orbiter balance beam.

The aft load is carried through the vertical runs of the LO_2 and LH_2 feed lines, which are bushed, hollow bolts securing the ET to the orbiter balance block. The simulated aft ET/SRB attach hardware is of stainless steel and does not carry load.

Detailed external tank protuberances are provided and these are fabricated of 17-4 stainless and are secured by 3-48 FHCS holding integral mounting buttons into recesses in the tank. The pressure and feed lines are as previously used on model 47-T on the 331-inch tank, the ellipsoid fairings and cable trays are of necessity new construction.

The finer details of this plumbing and the attachment of the button are accomplished with silver solder. Scanivalve and balance cables and pressures are routed into the tank from the orbiter through the hollow rear attach bolts (1/4-inch I.D.) and these and the cables from the tank Scanivalves are led out to the SRB's just behind the SRB front attach. The entire tank and it's protrusions are pressure instrumented.

The two aluminum SRB's are reworked from a previous usage with the principal alterations being to the protuberances, the number of pressure taps (added to reflect the requests of the customer), and the mode of attaching the SRB to the ET. The SRB to ET attachments were modified to bear the expected loads and to carry the electrical leads through from the tank.

The SRB's are fabricated of 2024-T4 aluminum alloy to reduce weight. The weight of the right hand SRB is approximately 40 pounds and the weight of the thinner, left hand SRB with the Scanivalves is approximately 21 pounds. Safety factors of three (3) for yield and five (5) for ultimate have been observed in this design.

Both SRB's are built around a 2.00-inch I.D. x 3.38-inch O.D. aluminum sleeve. This sleeve is to be pinned to the eccentric adapter and to the body of the SRB with two 1/4-inch pull pins on each side. The SRB itself consists of four main parts, a nose cone, a forebody, an aft attach ring and an aft body and nozzle assembly.

The SRB's are built up around the forebody with all instrumentation installed and are then slipped into the mounting holes in the tank. The aft body, spacer skirt, nozzle and thermal protecting shield of 2024 aluminum alloy are assembled with 2-56, 6-32 and 8-32 AHCS and installed as a unit on the forebody, sandwiching the 17-4 stainless steel aft attach ring between them. This ring is carved of a single piece of stock with integral different size mounting studs that simulate the aft attach struts, the studs being threaded on the inboard end.

A 7/16 AHCS passes through the simulated SRB/ET front attach to secure the front of the SRB to the ET, the nuts for this bolt and the two rear studs are inside of the ET. The nose cone, which is of 2024 aluminum alloy, slips over the forebody of the SRB after the booster is secured to the external tank, and is fastened with four 6-32 AHCS.

Nozzle actuator struts are simulated on each of the SRB aft skirts. The SRB aft separation thrusters are of aluminum alloy and are attached to the skirt with 6-32 AHCS and locating pins. The cable tunnel is of aluminum alloy and is secured with 2-56 AHCS. The skirt stiffeners are of aluminum alloy and are both bonded and attached with 1-64 FHCS. The SRB stiffener rings (4) are of 17-4 stainless steel and are split to fit over the skirt and snap into a locating groove. They are secured by filling the remainder of the groove with Renite, an epoxy filler resin. The forward attach lug, just aft of the ET lug with the 7/16-inch securing screw, is hollowed out to provide a 3/8-inch x 3/4-inch passage for instrumentation leads.

The left hand SRB is instrumented with pressure taps and a multiple Scanivalve unit. To provide access to the valves, a cover is fit to the LH forebody and is secured with 6-32 AHCS. All reference pressures, and instrumentation leads from the SRB are run internal to the LH fork of the sting.

The following nomenclature, illustrated in Figures 2b through 2d, was used to designate the model components:

Symbol	Description
B_{62}	-140 A/B Body
C_9	-140 A/B Canopy
E_{64}	OV 102 Elevon
W_{131}	OV 102 Wing

CONFIGURATIONS INVESTIGATED (Concluded)

Symbol	Description
M_{16}	Short OMS pods, -140 C w/nozzles
N_{112}	SSME nozzles, OV102 complete
R_5	146 A Rudder
V_8	146 A Vertical Tail
FD_3	Flipper Doors

A configuration code has not been assigned for the SILTS pod.

T_{39}	External Tank complete 330-inch O.D. with protuberances
S_{27}	Solid Rocket Booster complete 146-inch O.D. with protuberances

TEST FACILITY DESCRIPTION

This tunnel is one of the supersonic legs of the Ames Unitary facility. It is a closed circuit, variable density, continuous flow tunnel. The test section is 9 feet by 7 feet by 18 feet and the nozzle is of the asymmetric, sliding-block type in which the variation of the test section Mach number is achieved by translating, in the streamwise direction, the fixed contour block that forms the floor of the nozzle. The temperature in all three circuits is controlled by after-cooling. Dry air for use in the circuit is supplied from four 30,000 cubic-foot spherical tanks. The tunnel drive motors and compressor also serve the 8 by 7-foot tunnel. The motors have a combined output of 180,000 horsepower for continuous operations or 216,000 horsepower for one hour.

TEST PROCEDURE

The model was mounted upright in the tunnel on a steel forked sting supplied by Rockwell International. This sting was mounted to a primary taper adapter supplied by Ames Research Center and built by General Dynamics, Fort Worth. This adapter, through a system of arms and pivots, is designed to maintain the model in the center of the tunnel during angle-of-attack sweeps.

The model was instrumented so that pressure and force data could be obtained simultaneously, except on the vertical tail where both pressure instrumented and force (strain gauge) instrumented vertical tails were used. In general, only those model pressures were recorded which are aft of orbiter model Station $X_O = 33$ (model scale). This corresponds with ET Station $X_T = 55.23$ and SRB Station 38.94. Pressures on the AADS probe (only taps 1901 and 1902), ET 40 degree cone taps 1010, 1012, 1014, and 1016 at $X/LT = 0.02$ (Phi = 0, 90, 180, and 270°, respectively), and some of the pressures on the attach structure and protuberances were also measured. Figures 2e through 2p and Tables IV and V give the locations of the measured pressures.

All model pressures were measured using four gangs of Scanivalves mounted in the various elements of the model. Information on the Scanivalve installations and the pressure tap assignments to each valve are given in Reference 1, with any changes denoted in the Remarks section of this report.

The orbiter was mounted on the ET by means of the AEDC/PWT MK XXII 2.5-inch Task balance. The existing suspension system and balance sleeve for the MK XXXI balance (same dimensions as the MK XXII) were used.

The right hand wing was mounted on a single beam three-component balance which supports the panel in all degrees of freedom. Two bending moment and one torsion moment flexures were provided. The metric gap was fitted with a labyrinth seal and fouling indicator. A thin strip of low density foam was installed in the metric gap to minimize airflow through the gap. Due to an electrical problem, the fouling indicator was not operational during the test.

The previously manufactured dummy balance used with the "force" vertical, has been machined and gauged to form a four component balance. The balance has two yawing moment (side force) gauges, one roll (torsion) gauge and one pitching moment gauge. The sole purpose of the pitching moment gauge is to allow for the determination of interactions due to axial forces acting on the vertical tail. The initial configuration included the pressure instrumented vertical. "Quick-disconnect" plugs in the pressure tubing were used to permit a rapid change from the "pressure" to the "force" vertical tail.

The right hand elevons were instrumented to measure hinge moment directly via a beam that supports the panel in torsion about a hinge line coincident with the scale hinge line. Thus, the output of the strain gauge bridge was directly proportional to the applied moment. Deflection angles used for this test are given in Table III.

An ARC-supplied angular position indicator (dangleometer) was mounted in the external tank, and was used to position the model in pitch during the test.

The pressure transducers were not calibrated prior to the test but were check calibrated after the model was installed in the tunnel using the "reference" and "calibrate" ports on the Scanivalves in accordance with normal ARC procedures.

After installation all pressures were either leak checked using a hand-held vacuum pump or continuity checked with shop air when the orifice was located in a position where it could not be leak checked. Leak checks were performed during model changes to check all pressures which had been disconnected during the model change.

The 2 1/2-inch MK XXII balance and the vertical tail balance were calibrated in the ARC calibration laboratory prior to the test. The wing calibration used for test OA146 was used for this test. The elevon hinge moment gauges were calibrated in the tunnel after the model was installed, and were check calibrated after each change in elevon angle. All balances were check-loaded after the model was installed in the tunnel.

After installation in the model the dangleometer was calibrated over the angle-of-attack range required for the test.

The general test procedure was as follows: After starting the tunnel the desired test conditions for a particular Mach number (the lowest required for the subject configuration) were established as given in Table I. The tunnel horizontal strut was then positioned to give the required angle-of-sideslip and the model was then pitched through the angle-of-attack range called for in the run schedule using the General Dynamics articulated sting. Data were obtained during a pause at each required angle-of-attack. After data were obtained in this manner at all angles-of-sideslip at a particular Mach number, the test conditions were changed to the next higher Mach number and the process was repeated. After all data on a particular configuration had been obtained, the tunnel was shut down for a model change to the next scheduled elevon setting. Periodically, the AADS probe was rotated in 90-degree increments so that data were obtained on the AADS pressure taps in four different positions. The change from the "pressure" to the "force" vertical tail was made during the non-running shift to provide sufficient time to check out the balance. The SILTS pod was also removed during a non-running shift to minimize model change time during the running shift.

DATA REDUCTION

Standard ARC methods for computing tunnel parameters, balance forces and moments, and model attitudes were used. Pressure coefficients were calculated for all model pressures. Force and moment coefficients (body axis system only) were computed for each balance using the axis system defined in Figure 1a. Orbiter force and moment data were adjusted to account for the difference between measured base pressure and freestream pressure. Elevon hinge moments, and wing and vertical tail forces and moments were calculated in coefficient form about reference locations specified for each component.

The moment reference locations, in full-scale dimensions, are as follows:

Total vehicle (Used for orbiter data):	X_T 976, Y_T0, Z_T 400
Right wing:	X_O 1307, Y_O 105
Right elevons:	Hingeline at X_O 1387
Vertical tail:	X_O 1414.3, Z_O 503

The attitude of the external tank/SRB's was calculated from the sector reading and the output of the dangleometer mounted in the external tank. Balance deflections were accounted for in determining the attitude of the orbiter. The deflection of the elevons and the vertical tail due to applied loads was also calculated. The deflection of the wing under load was found to be insignificant and therefore was not accounted for in data reduction.

Pressure coefficients were computed as follows:

$$C_{p_i} = (P_i - P_o)/q$$

where "i" represents the model orifice number.

Standard six component body axis force coefficients were computed for the balance mounted orbiter. The reference area used was the orbiter wing area, and the reference length for moment coefficients was the orbiter reference length. Moments were computed at the integrated vehicle reference center which is at the orbiter nose on the tank centerline. This is located at $X_T = 976$, $Y_T = 0$, $Z_T = 400$ in tank coordinates, and $X_o = 235$, $Y_o = 0$, $Z_o = 63.5$ in orbiter coordinates. The balance transfer dimensions are depicted in Figure 1c.

The normal force, axial force, and pitching moment coefficients for the orbiter were adjusted for base pressure as follows:

$$C_{N_B} = \frac{-1}{S_w} \tan 14.75^\circ \sum_{301}^{324} C_{p_i} A_i + \frac{-1}{S_w} \sum_{401}^{440} C_{p_i} A_i$$

$$C_{A_B} = \frac{-1}{S_w} \sum_{301}^{324} C_{p_i} A_i$$

$$C_{m_B} = \frac{-1}{S_w b} -X_1 \tan 14.75^\circ \sum_{301}^{324} C_{p_i} A_i -X_2 \sum_{401}^{440} C_{p_i} A_i +Z_1 \sum_{301}^{324} C_{p_i} A_i$$

where X_1, X_2 and Z_1 are the distances to the centroid of the area from the moment reference center.

The resulting coefficients are applied as follows to obtain the forebody coefficients:

$$C_{A_f} = C_{A_u} - C_{A_B}$$

$$C_{N_f} = C_{N_u} - C_{N_B}$$

$$C_{m_f} = C_{m_u} - C_{m_B}$$

The model component loads were reduced to force and moment coefficients in the following manner:

For wing bending and torsion: (See Figure 1d for wing MRC)

$$C_{N_w} = N_w/[(q)(S_w)]$$

$$C_{B_w} = B_w/[(q)(S_w)(b_w)]$$

$$C_{T_w} = T_w/[(q)(S_w)(\bar{c})]$$

For wing center-of-pressure:

$$X_{CP_w} = 1307 - \frac{C_{T_w}}{C_{N_w}} \frac{\bar{c}}{0.03}$$

$$Y_{CP_w} = 105 + \frac{C_{B_w}}{C_{N_w}} \frac{b_w}{0.03}$$

For vertical tail bending and torsion: (See Figure 1e for VT MRC)

$$C_{S_v} = N_{vt}/[(q)(S_{vt})]$$

$$C_{B_v} = B_{vt}/[(q)(S_{vt})(C_{vt})]$$

$$C_{n_v} = T_{vt}/[(q)(S_{vt})(C_{vt})]$$

(Data from the vertical tail pitching moment gauge were not reduced.)

DATA REDUCTION (Continued)

For vertical tail center-of-pressure:

$$X_{CP_v} = 1414.3 - \frac{Cn_v}{Cs_v} \frac{C_{vt}}{0.03}$$

$$Y_{CP_v} = 503 + \frac{CB_v}{Cs_v} \frac{C_{vt}}{0.03}$$

For elevon hinge moments:

$$Ch_{e_i} = H_{e_i}/[(q)(S_e)(C_e)]$$

$$Ch_{e_o} = H_{e_o}/[(q)(S_e)(C_e)]$$

A schedule of completed runs is given in Table II which is the Data Set/Run Number Collation Summary for the test.

Reference dimensions and constants used were:

SYMBOL	VALUE MODEL SCALE	VALUE FULL SCALE	DESCRIPTION	
A_{301}	- 0 -		Orbiter base area for pressure tap	301
A_{302}	0.022146 ft.^{2}			302
A_{303}	0.122387			303
A_{304}	0.005970			304
A_{305}	0.004909			305
A_{306}	0.009287			306
A_{307}	0.007960			307
A_{308}	0.010613			308
A_{309}	0.022554			309

DATA REDUCTION (Continued)

SYMBOL	VALUE: MODEL SCALE	VALUE: FULL SCALE	DESCRIPTION
A_{310}	0.003980		Orbiter base area for pressure tap 310
A_{311}	0.023217		311
A_{312}	0.016584		312
A_{313}	0.001327		313
A_{314}	0.011940		314
A_{315}	0.013798		315
A_{316}	0.007297		316
A_{317}	0.012603		317
A_{318}	0.017247		318
A_{319}	0.021758		319
A_{320}	0.015920		320
A_{321}	0.017247		321
A_{322}	0.014328		322
A_{323}	0.006103		323
A_{324}	0.026003		324
A_{401}	- 0 -		Body flap base area for pressure tap 401
A_{402}	- 0 -		402
A_{403}	- 0 -		403
A_{404}	- 0 -		404
A_{405}	0.01151 $ft.^2$		405
A_{406}	0.010267 $ft.^2$		406
A_{407}	0.0089838 $ft.^2$		407

DATA REDUCTION (Continued)

SYMBOL	VALUE MODEL SCALE	VALUE FULL SCALE	DESCRIPTION
A408	0.0077004 ft.		Body flap base area for pressure tap 408
A409	- 0 -		409
A410	- 0 -		410
A411	- 0 -		411
A412	- 0 -		412
A413	0.012834 ft.^{2}		413
A414	0.012834 ft.^{2}		414
A415	0.012834 ft.^{2}		415
A416	0.012834 ft.^{2}		416
A417	- 0 -		417
A418	- 0 -		418
A419	- 0 -		419
A420	- 0 -		420
A421	- 0 -		421
A422	- 0 -		422
A423	- 0 -		423
A424	- 0 -		424
A425	- 0 -		425
A426	- 0 -		426
A427	- 0 -		427
A428	- 0 -		428
A429	- 0 -		429
A430	- 0 -		430

SYMBOL	VALUE MODEL SCALE	FULL SCALE	DESCRIPTION
A_{431}	- 0 -		Body flap base area for pressure tap 431
A_{432}	- 0 -		432
A_{433}	- 0 -		433
A_{434}	- 0 -		434
A_{435}	- 0 -		435
A_{436}	- 0 -		436
A_{437}	.011551 ft.^{2}		437
A_{438}	.010267 ft.^{2}		438
A_{439}	.0089838 ft.^{2}		439
A_{440}	.0077004 ft.^{2}		440
b	38.709 in.	1290.3 in.	Orbiter reference length
b_w	28.101 in.	936.7 in.	Wing bending reference length
$\bar{c}$	14.244 in.	474.8 in.	Mean aerodynamic chord
C_e	2.721 in.	90.7 in.	Elevon reference chord length
C_{vt}	5.994 in.	199.8 in.	Vertical tail reference chord length
S_e	0.189 ft.^{2}	210.0 ft.^{2}	Elevon reference area
S_w	2.421 ft.^{2}	2690. ft.^{2}	Wing reference area
S_{vt}	0.3719 ft.^{2}	413.25 ft.^{2}	Vertical tail reference area
X_1	37.890 in.		Base pressure transfer distance
X_2	39.890 in.		Base pressure transfer distance
X_T	-25.570 in.	-852.33 in.	Longitudinal transfer distance from orbiter balance reference point to integrated vehicle MRC

DATA REDUCTION (Concluded)

SYMBOL	VALUE MODEL SCALE	FULL SCALE	DESCRIPTION
X_{TV}	2.341 in.	78.03 in.	Longitudinal transfer distance from vertical tail balance reference center to vertical tail MRC
Z_1	9.795 in.	-326.5 in.	Base pressure transfer distance
Z_T	-9.795 in.	-326. 5 in.	Vertical transfer distance from orbiter balance center-line to integrated vehicle MRC
Z_{TV}	0.632 in.	21.07 in.	Vertical transfer distance from vertical tail balance centerline to vertical tail MRC

REFERENCES

1. STS-79-0016, "Pretest Information for Test IA184 of the 0.03-Scale Pressure Loads Model 47-OTS of the Space Shuttle Integrated Vehicle in the 9 x 7-Foot Supersonic Test Section of the Unitary Plan Wind Tunnel at Ames Research Center," dated March 5, 1979.

2. SD77-SH-0227, "Pretest Information for Test IA105B of the 0.03-Scale Pressure Loads Model 47-OTS of the Space Shuttle Integrated Vehicle in the 9-Foot by 7-Foot Supersonic Test Section of the Unitary Plan Wind Tunnel at NASA/Ames Research Center," dated October 12, 1977.

3. "Research Facilities Summary, Volume II - Wind Tunnels: Subsonic, Transonic, Supersonic," NASA/Ames Research Center, dated December, 1965.

TABLE I.

TEST : IA184

DATE : April 1979

TEST CONDITIONS

MACH NUMBER	REYNOLDS NUMBER (per foot)	DYNAMIC PRESSURE (pounds/sq.ft.)	STAGNATION TEMPERATURE (degrees Fahrenheit)
1.55	3.5×10^6	785	120
1.8	3.5×10^6	790	120
2.2	3.5×10^6	760	120
2.5	3.5×10^6	710	120

BALANCE UTILIZED: AEDC/PWT MK XXII 2.5-INCH TASK

	CAPACITY:	ACCURACY:	COEFFICIENT TOLERANCE:
NF	5,000 lbs	±.5%	
SF	2,000 lbs		
AF	800 lbs		
PM			
RM	4,000 in-lbs		
YM			

COMMENTS:

TABLE II.

TEST: IA184 — DATA SET/RUN NUMBER COLLATION SUMMARY — DATE: April 1979

DATA SET IDENTIFIER	CONFIGURATION	α	β	δe	δa	M	HADS	SIDE	BETA −6	BETA −4	BETA 0	BETA 4	BETA 6
** R3K001	OTS (PRESS. TAIL)	A	C	4	−5	1.8	0	ON	4*	5*	6	7	8
02		B				2.2			9	10	11	12	13
03		B				2.5			14	15	16	17	18
04		B			2	2.5	90		20	21	22	23	24
05		A			−7	1.8			26	27	28	29	30
06		B				2.2			31	32	33	34	35
07		B				2.5			36	37	38	39	40
08		A	D	8		1.55			48		49		50
09		A	C			1.8			43	44	45	46	47
10	ØTS (FORCE TAIL)	A				1.55	180		53	54	55	57	56
11		B				2.5			58	59	60	61	62
12		A		10		1.55			65	66	67	68	69
13		A				1.8			70	71	72	73	74
14		B				2.2			75	76	77	78	79
15		B		0		2.2	270	OFF	82	83	84	85	86
16		B				2.5			87	88	89	90	91
17		B			0	2.2			93	94	95	96	97
18		B				2.5			98	99	100	101	102

α OR β SCHEDULES — COEFFICIENTS

A: α = −6, −4, −2, 0, 2, 4

B: α = −4, −2, 0, 2, 4, 6

C: β = −6, −4, 0, 4, 6

D: β = −6, 0, 6

* BETA = 0.5

** REFER TO PAGE 44 FOR COEFFICIENT SCHEDULES

TABLE II. (Continued)

TEST:

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE: April 1979

DATA SET IDENTIFIER	CONFIGURATION	α	β	Sci	Seo	M	AADS	SILTS					BETA -6	-4	0	4	6
R3K019	OTS (FORCE TAIL)	A	C	12	-2	1.8	270	OFF					111	112	113	114	115
20	OTS (FORCE TAIL GAPS SEALED)	B	D	0	0	2.5	↓	↓					104		105		106
21	↓	↓	↓	↓	↓	2.2	↓	↓					107		108		109

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS

IDVAR (1) IDVAR (2) NDV

α OR β SCHEDULES

TABLE II. (Concluded)

DATASET/RUN NUMBER COLLATION SUMMARY

DATASET IDENTIFIER 1st CHARACTER	INDEPENDENT VARIABLE FIRST	INDEPENDENT VARIABLE SECOND	FORCE DATA COEFFICIENT SCHEDULE										
E	BETAØ	ALPHAØ	MACH	CNU	CAU	CLMU	CY	CYN	CBL	CNF	CAF	CLMF
F	BETAØ	ALPHAØ	ALPHAT	BETAT	CNW	CTW	CBW	XCPW	YCPW	CAB	CNB	CLMB
T	BETAØ	ALPHAØ	CSV	CTV	CBV	XCPV	ZCPV					
U	BETAØ	ALPHAØ	CHEI	CHEØ	ELVRI	ELVRØ	ELØ	ELI	ERØ	ERI	DØ	DI
V	BETAØ	ALPHAØ	RN/L	PT	P	Q(PSF)	CP1010	CP1012	CP1014	CP1016	CP1901	CP1902

4th CHARACTER			PRESSURE DATA COMPONENT
B	BETAØ	ALPHAØ	ORBITER FUSELAGE
E	BETAØ	ALPHAØ	ORBITER BASE
G	BETAØ	ALPHAØ	BODY FLAP, TOP
F	BETAØ	ALPHAØ	BODY FLAP, BOTTOM
V	BETAØ	ALPHAØ	VERTICAL TAIL
U	BETAØ	ALPHAØ	LH WING UPPER SURFACE
L	BETAØ	ALPHAØ	LH WING LOWER SURFACE
T	BETAØ	ALPHAØ	EXTERNAL TANK
S	BETAØ	ALPHAØ	LEFT SRB
M	BETAØ	ALPHAØ	EXTERNAL TANK PROTUBERANCES
N	BETAØ	ALPHAØ	SRB PROTUBERANCES
J	BETAØ	ALPHAØ	MISCELLANEOUS

TABLE III. ELEVON DEFLECTION ANGLES

INBOARD ELEVON ANGLES, DEGREES		
NOMINAL	LEFT HAND MEASURED	RIGHT HAND MEASURED
12	12.45	12.60
10	10.58	12.60
8	8.32	8.45
4	4.45	4.58
0	0	0

OUTBOARD ELEVON ANGLES, DEGREES		
NOMINAL	LEFT HAND MEASURED	RIGHT HAND MEASURED
+2	2.23	2.42
0	0	0
-2	-1.78	-1.72
-5	-4.98	-4.98
-7	-6.88	-6.82

TABLE IV. MODEL 47 ORBITER FUSELAGE PRESSURE TAP ASSIGNMENTS

ORBITER STATION		ϕ - RADIAL LOCATION ~ DEGREES													
FULL	X'_o/L_o	0	20	40	70	82	90	105	110	120	135	150	165	180	Σ
1129	.6929					161									1
1215	.7595	162		163	164		165	166		167	168	169	170	171	10
1300	.8254	173		174	175		176	177		178	179	180		181	9
1318	.8393								218	219	220	221	222		5
1360	.8641								223	224	225	226	227		5
1375	.8835	183		184	185		186	187		188	189	190	191	192A	10
1390	.8951				193										1
1430	.9261	194		195	196		197	198		199	200	201	202	203A	10
1455	.9455												212A	213A	2
1480	.9649	204		205	206		207	208		209	210	211	212		9
1530a	1.0036								214	215					2
1530b	1.0036								216	217					2
1548*	1.018	409	417	433											3*
1580*	1.043	410	418	434											3*
1609*	1.0648	411	419	435											3*
1613*	1.0680	412	420	436											3*
														TOTAL	78*/66

NOTES: L_o = 1290.3 Inches

Taps 214, 215 Inside Base Region

* Also Included in Body Flap Table

TABLE V. MODEL 47 EXTERNAL TANK BASE PRESSURE TAP ASSIGNMENTS

RADIUS FULL SCALE	ϕ - DEGREES															
	0	15	30	45	60	90	112.5	135	157.5	180	202.5	225	247.5	270	300	330
166.5 (Tank)																
156.56	1502		1503	1501	1504	1505	1506	1507	1508	1509	1510	1511	1512	1513	1514	1515
148.12	1516		1517		1518	1519	1520	1521	1522	1523	1524	1525	1526	1527	1528	1529
139.02	1530	1531	1532	1533	1534	1535	1536	1537	1538	1539	1540	1541	1542	1543	1544	1545
105.09	1546		1547		1548	1549	1550	1551	1552	1553	1554	1555	1556	1557	1558	1559
77.48	1560		1561		1562	1563	1564	1565	1566	1567	1568	1569	1570	1571	1572	1573
0	1574															

TABLE VI. BAD PRESSURE DATA LIST (IA184)

COMPONENT	DATASET	BETA	ALPHA	GEOMETRY 1	GEOMETRY 2	PRESSURE TAPS
FUSELAGE				X/LB	PHI	
	R3KB07	0.126	3.666	1.018 to 1.065	40	433,434,435
				0.926, 0.964	60	294,297
				0.884, 0.965	70	185,206
				1.0	110	216
				0.884, 1.0	120	188,217
	R3KB08	-6.040	-6.303	ALL	ALL	ALL
	R3KB19	4.776	-6.215	1.043 to 1.065	20	417,418,419
				0.864, 0.965	135	225,210
WING, UPPER				XW/CW	Y/BW	
	R3KU04	-6.352	-2.451	0.55,0.7,0.836, 0.971	0.299	630,631,633,638
				0.4, 0.7	0.342	663,665
	R3KU07	0.126	3.666	0.809 to 0.895	0.342	667,668,669,670
	R3KU08	-6.040	-6,303	ALL	ALL	ALL
	R3KU19	4.776	-6.215	0.4,0.55,0.7	0.342	663,664,665
				0.868 to 1.0	0.427	703,704,705, 706
				1.0	0.534	738
				0.902 to 1.0	0.619	768,769,770
				0.841 to 1.0	0.726	799,800,801,802
				0.888 to 1.0	0.811	831,832,833
				0.876 to 1.0	0.897	861,862,863
WING, LOWER				XW/CW	Y/BW	
	R3KL04	-6.352	-2.451	0.7, 0.866	0.299	648,651
	R3KL07	0.126	3.666	0.93	0.342	688
				0.55 to 0.824	0.427	714,715,716,717,718
				0.25 to 0.738	0.534	744,745,746,747,748
				0.08 to 0.4	0.619	774,775,776,777
				0.673 to 0.725	0.619	779,780

TABLE VI. BAD PRESSURE DATA LIST (Continued)
(IA184)

COMPONENT	DATASET	BETA	ALPHA	GEOMETRY 1	GEOMETRY 2	PRESSURE TAPS
WING, LOWER (cont.)				XW/CW	Y/BW	
				0.05 to 0.25	0.726	805,806,807,808
				0.05 to 0.25	0.811	836,837,838,839
				0.05 to 0.642	0.897	866,867,868,869,870,871,872
				0.25 to 0.848	0.961	898,899,900,901,902,903,904
	R3KL08	-6.040	-6.303	0.08 to 0.4	0.534	742,743,744,745
				0.906 to 1.0	0.534	752,753,738
				0.05 to 0.15	0.619	773,774,775
	R3KL08	06.040	-6.303	0.953 to 1.0	0.619	785,770
				0.05 to 0.25	0.726	805,806,807,808
				0.896,1.0	0.726	816,817,802
	R3KL19	4.776	-6.215	0.862	0	183
				0.862	0.226	184
				0.911 to 1.0	0.299	653,654,655,639
				0.25,0.758,1.0	0.427	712,716,706
				0.08, 1.0	0.534	742,738
				0.01,0.4,1.0	0.619	771,777,770
				0.01,0.02,0.05, 1.0	0.726	803,804,805,802
				0.01,0.15,1.0	0.811	834,838,833
				0.02 to 0.642	0.897	865,866,867,868,869,870,871,872
				1.0	0.897	863
				0.08 to 0.848	0.961	896,897,898,899,900,901,902,903,904
VERTICAL TAIL				XV/CV	ZB/BV	
	R3KV08	-6.040	6.303	ALL	0.8	554,555,556,557,558,559,560,561,562
				0 to 0.52	0.919	563,564,565,566,567,568
				0.15,0.3,0.85	1.0	572,573,576
BODY FLAP, TOP				X/CBF	Y/BBF	
	R3KG01	0.500	-5.293	0.95	0.8	432
	R3KG03	0.146	1.754	0.95	0.65,0.8	424,432

TABLE VI. BAD PRESSURE DATA LIST (Continued)
(IA184)

COMPONENT	DATASET	BETA	ALPHA	GEOMETRY 1	GEOMETRY 2	PRESSURE TAPS
BODY FLAP,TOP (cont.)				X/CBF	Y/BBF	
		0.124	3.972	-0.10	0.65	421
		0.124	3.972	0.15	0.10	406
		4.559	-2.568	-0.10	0.10	405
	R3KG08	-6.040	-6.303	ALL	ALL	ALL
BODY FLAP, BOTTOM				X/CBF	Y/BBF	
	R3KF07	0.126	3.666	ALL	0.9	433,434,435,436
	R3KF08	-6.040	-6.303	ALL	ALL	ALL
	R3KF19	4.776	-6.215	0.6,0.95	0.65	419,420
				-0.1,0.2,0.6, 0.95	0.8	425,426,427,428
EXTERNAL TANK				XT/LT	PHI	
	R3KT07	0.126	3.666	0.992	60	1562
				0.956	135,202,225	1507,1510,1511
				0.931	247	1422
	R3KT07	0.126	3.666	0.863 to 0.931	300	1398,1411,1424
				0.831 to 0.931	330	1386,1399,1412,1425
	R3KT08	-6.040	-6.303	0.031,0.896, 0.97,1.0	0	1018,1400,1530,1574
				0.863 to 0.970	30	1388,1414,1503,1517,1532
				0.031, 0.931	90	1021,1416
				0.931	157	1419
				0.956	202,225	1510,1511
				0.031	270	1029
	R3KT19	4.776	-6.215	0.956	0,30	1502,1503
				0.985	60,90,112.5	1548,1549,1550
				0.992	135,157.5, 180	1565,1566,1567
				0.985,0.992	202	1554,1568

TABLE VI. BAD PRESSURE DATA LIST (Continued)
(IA184)

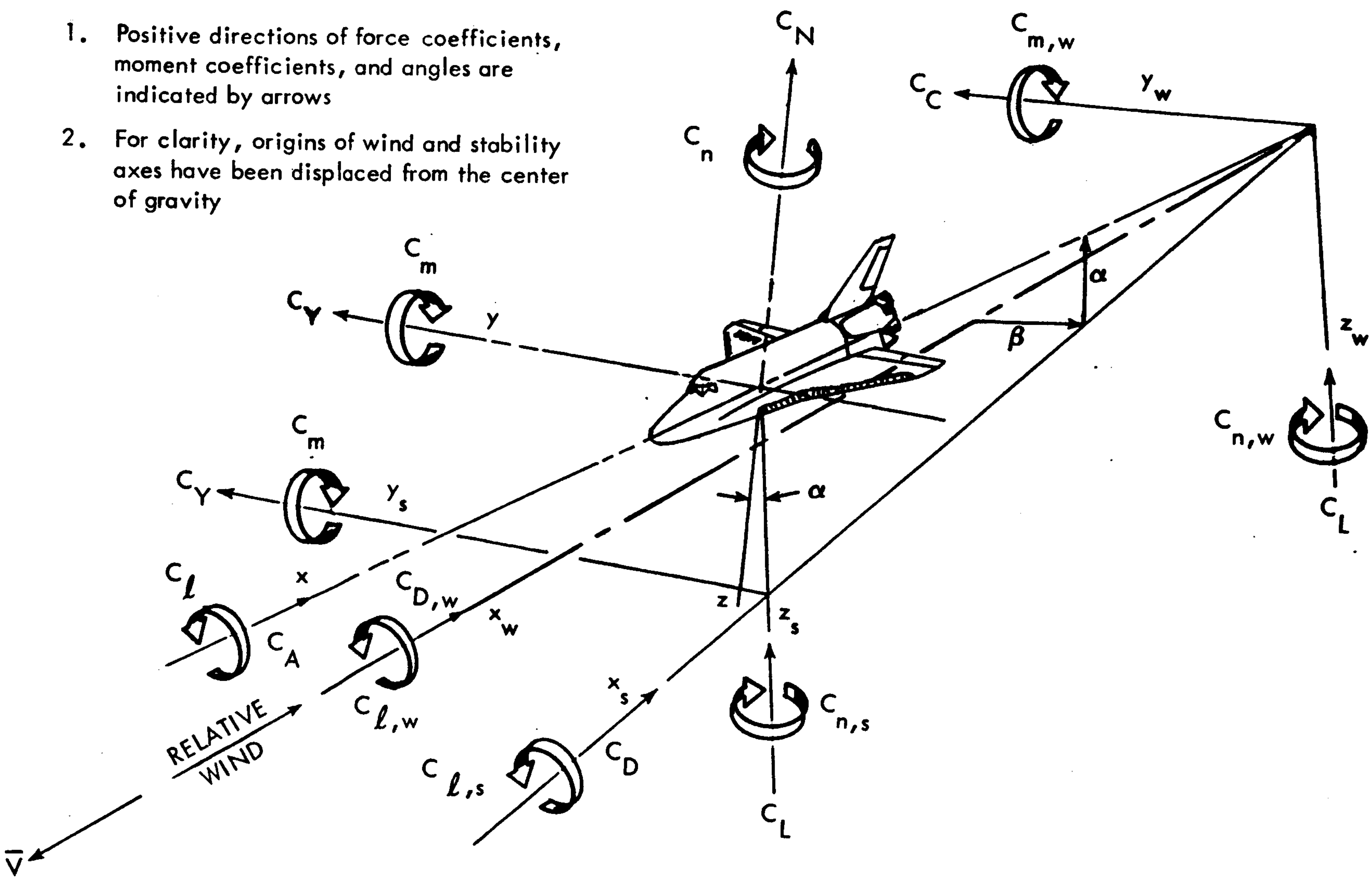
COMPONENT	DATASET	BETA	ALPHA	GEOMETRY 1	GEOMETRY 2	PRESSURE TAPS
EXTERNAL TANK (cont.)				XT/LT	PHI	
				0.956 to 0.992	247.5,300	1512,1526,1542,1556,1570,1514,1528,1544,1558, 1572
				0.831 to 0.896	330	1386,1399,1412
SRB, LEFT				XS/LS	PHI	
	R3KS07	0.126	3.666	1.0	45	2202
				0.659,0.753, 0.838,9.925,	86	2078,2089,2113,2129
				0.925,0.943	180	2132,2139
				0.925 to 0.997	270	2134,2141,2167,2148,2157,2177
				1.0	330	2210
	R3KS08	-6.040	-6.303	ALL	180 to 270	2001,2006,2007,2008,2014,2015,2016,2022,2023, 2024,2029,2030,2038,2039,2040,2047,2048,2049, 2054,2055,2056,2065,2066,2067,2074,2075,2076, 2083,2084,2085,2092,2093,2094,2099,2101,2106, 2108,2116,2117,2118,2123,2124,2125,2132,2133, 2134,2139,2140,2141,2146,2147,2148,2154,2155, 2156,2157,2164,2165,2166,2167,2174,2175,2176, 2177,2205,2206,2207,2208
				0.753,0.946, 0.959,0.997	315	2095,2149,2159,2179
	R3KS19	4.776	-6.215	0.946,0.959	45	2144,2151
				1.0	240	2207
				ALL	270	2008,2016,2024,2040,2049,2056,2067,2076,2085, 2094,2101,2108,2118,2125,2134,2141,2148,2157, 2167,2177,2208
ORBITER BASE				N/A	N/A	
	R3KE02 through R3KE07	ALL	ALL	-	-	301

TABLE VI. BAD PRESSURE DATA LIST (Concluded)
(IA184)

COMPONENT	DATASET	BETA	ALPHA	GEOMETRY 1	GEOMETRY 2	PRESSURE TAPS
ORBITER BASE (cont.)				N/A	N/A	
	R3KE03	0.146	1.754	-	-	312,316
		0.124	3.972	-	-	302,309,320
	R3KE08	-6.040	-6.303	-	-	ALL
	R3KE10 through R3KE21	ALL	ALL	-	-	301,302,308
	R3KE19	4.776	-6.215	-	-	319,320,321,322,323,324
ET PROTUBERANCES				N/A	N/A	
	R3KM07	0.126	3.666	-	-	1724,1769
	R3KM08	-6.040	-6.303	-	-	1766
SRB PROTUBERANCES				N/A	N/A	
	R3KN07	0.126	3.666	-	-	2356,2350
MISCELLANEOUS				N/A	N/A	
	R3KJ07	0.126	3.666	-	-	ALL
	R3KJ08	-6.040	-6.303	-	-	ALL
	R3KJ19	4.776	-6.215	-	-	214

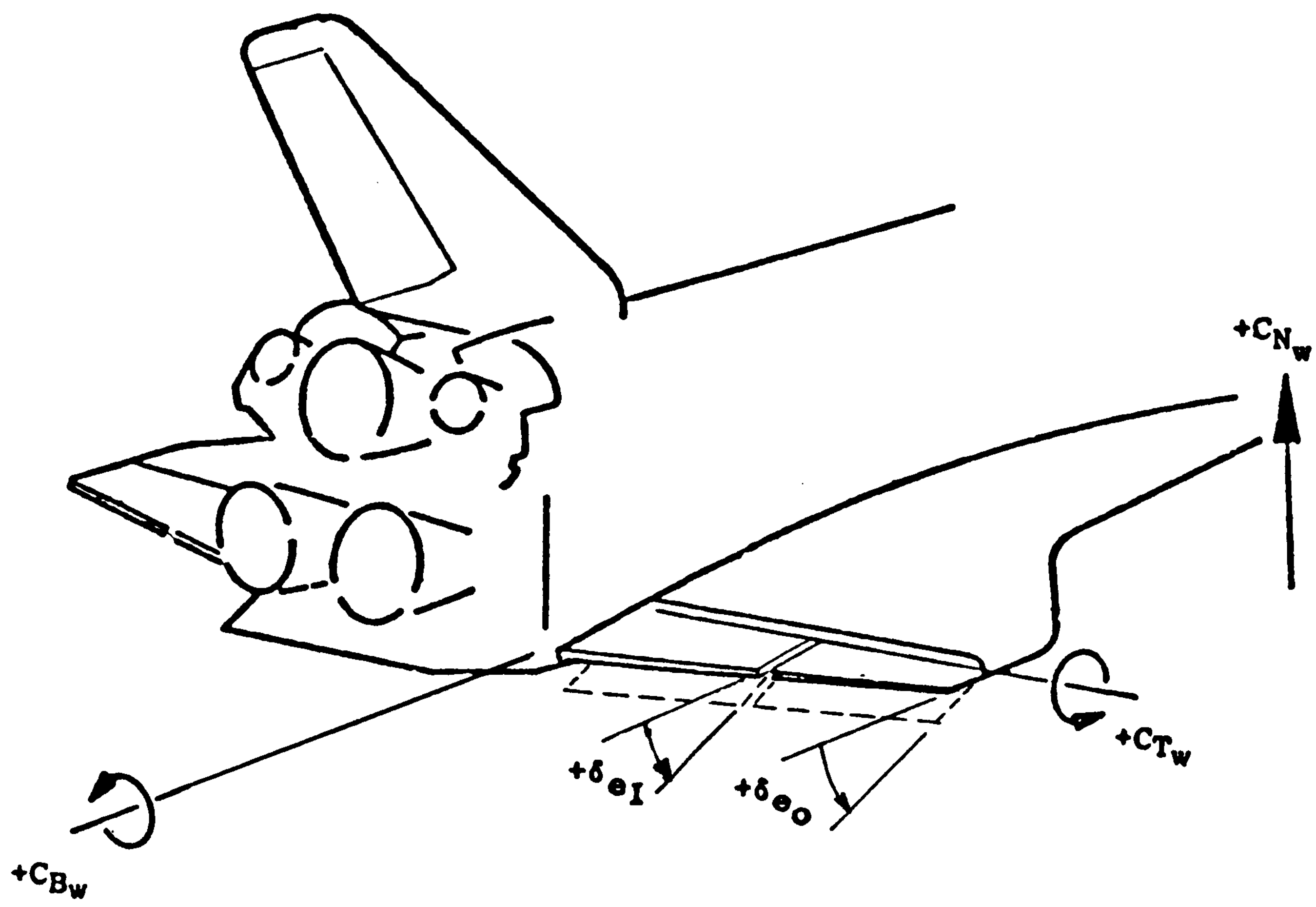
Notes:

1. Positive directions of force coefficients, moment coefficients, and angles are indicated by arrows
2. For clarity, origins of wind and stability axes have been displaced from the center of gravity

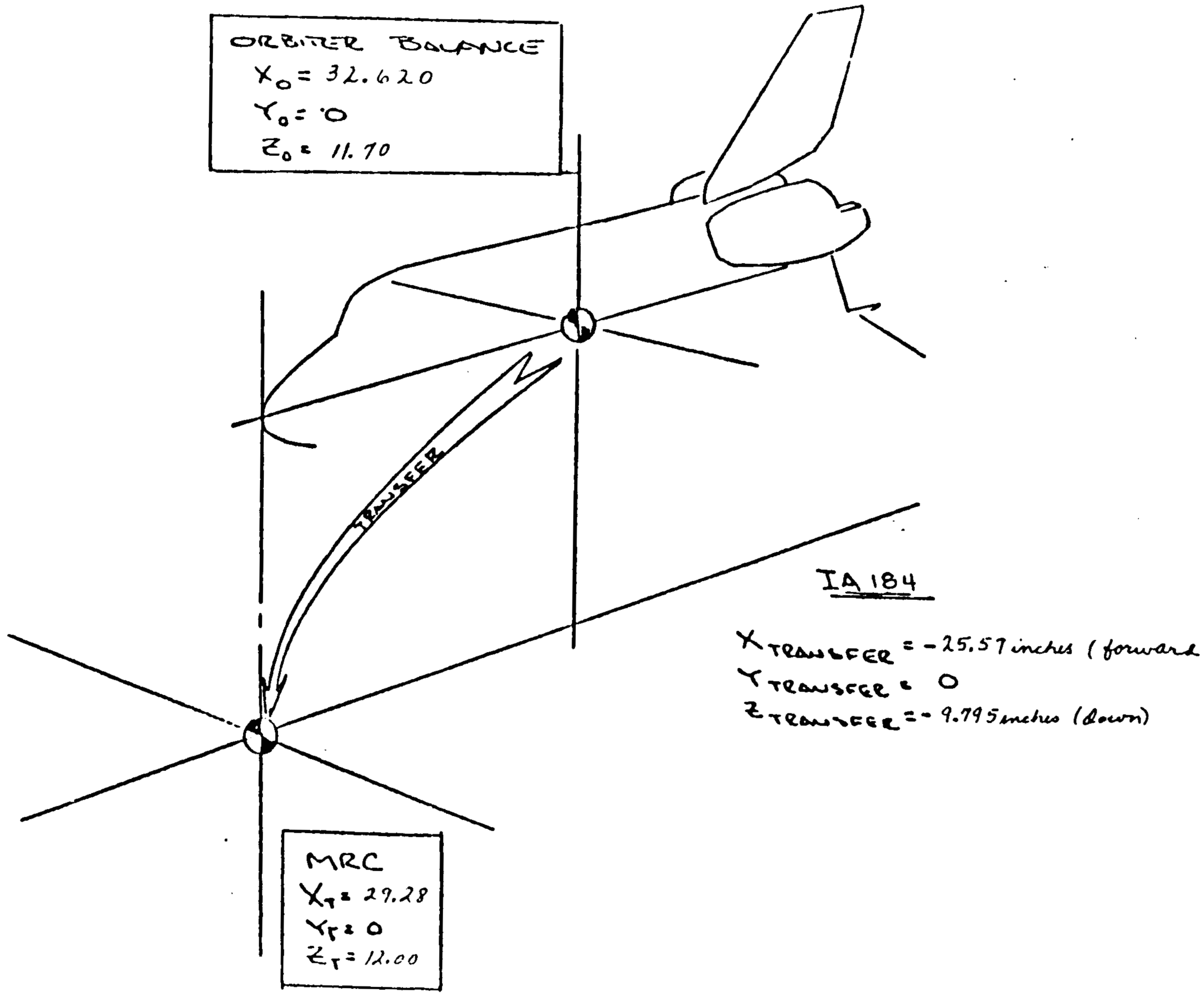


a. Axis Systems

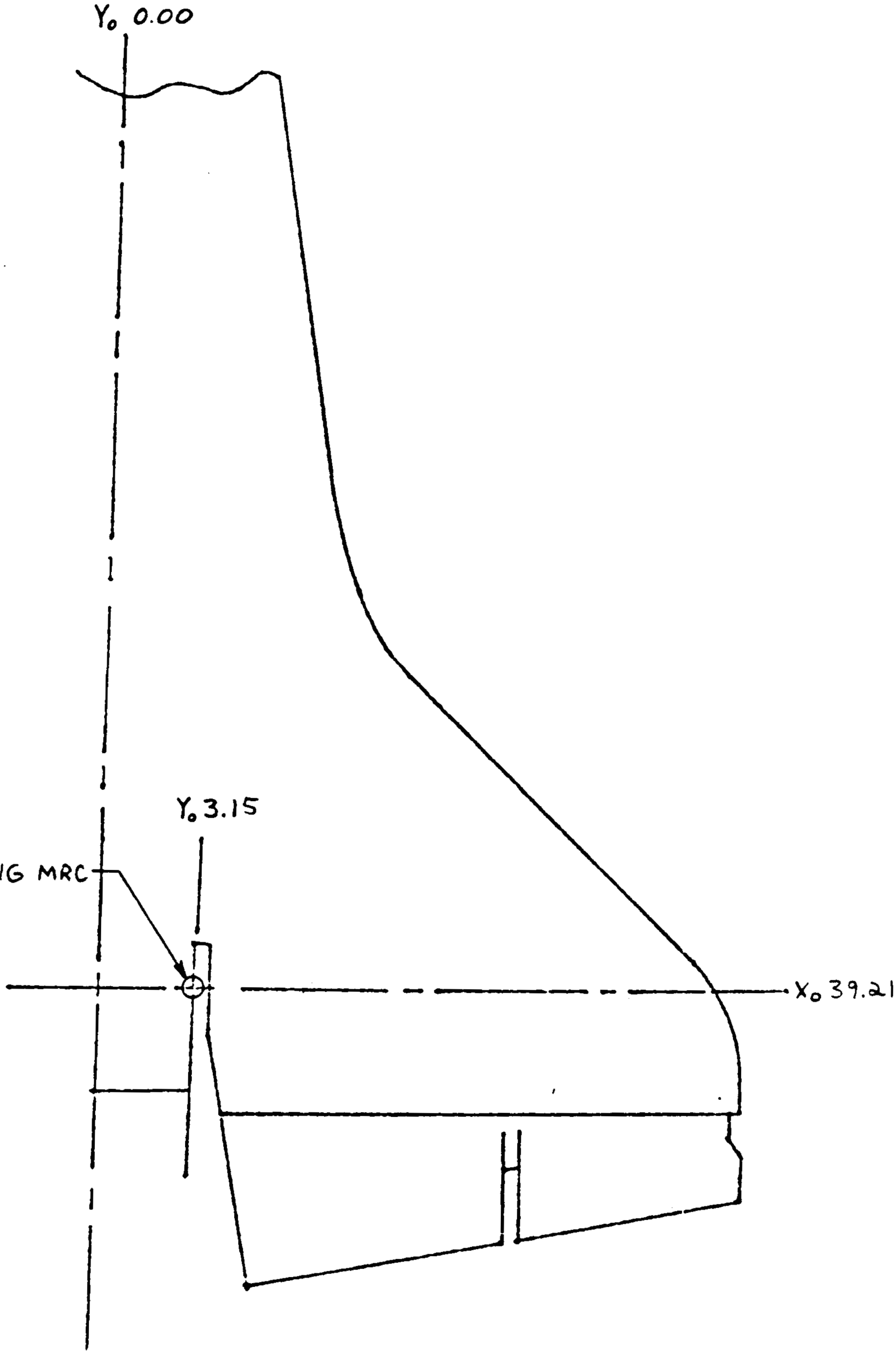
Figure 1. Model axis systems, sign conventions and reference dimensions.



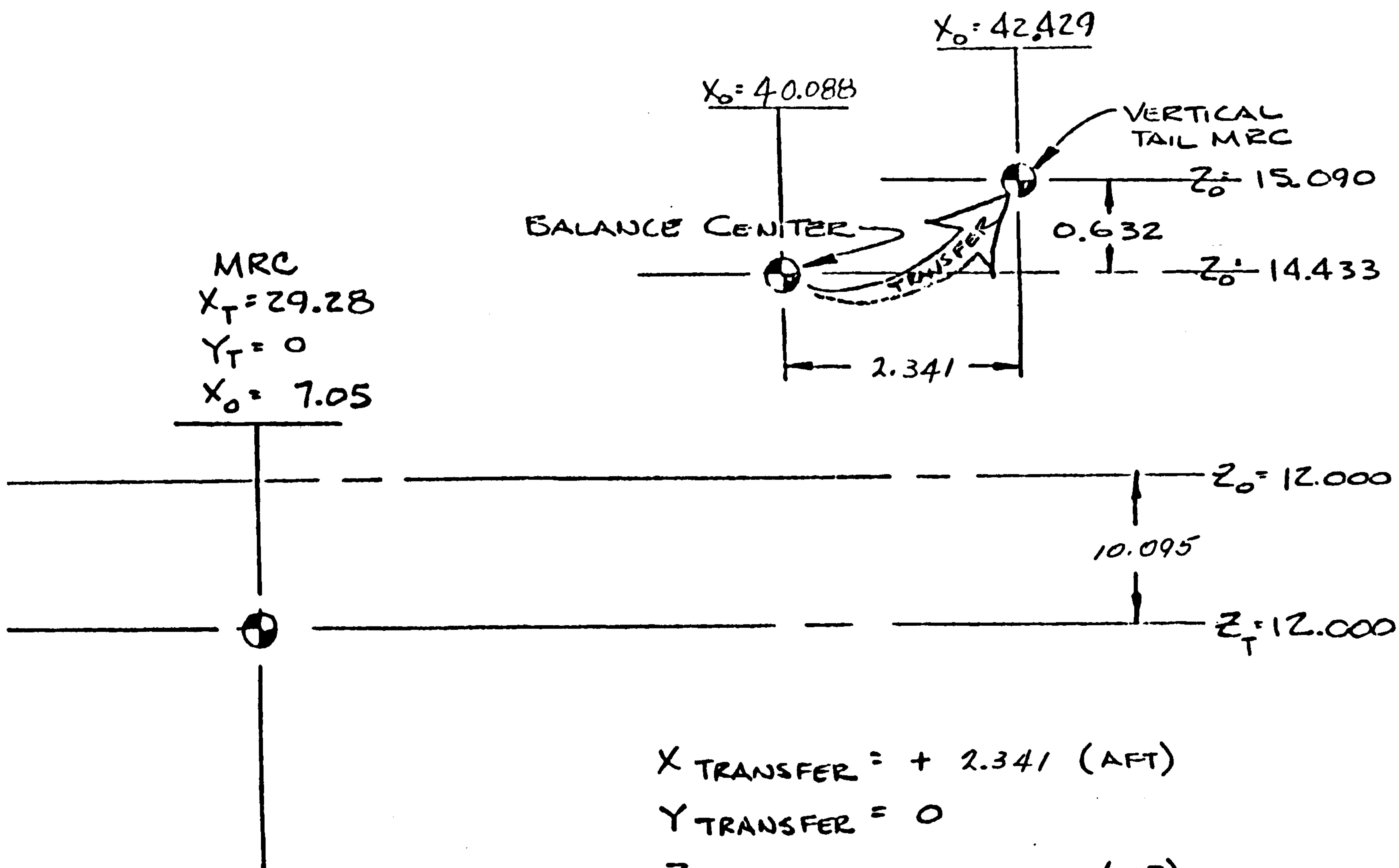
b. Definition of Deflection Angles and Wing Coefficients
Figure 1. Continued



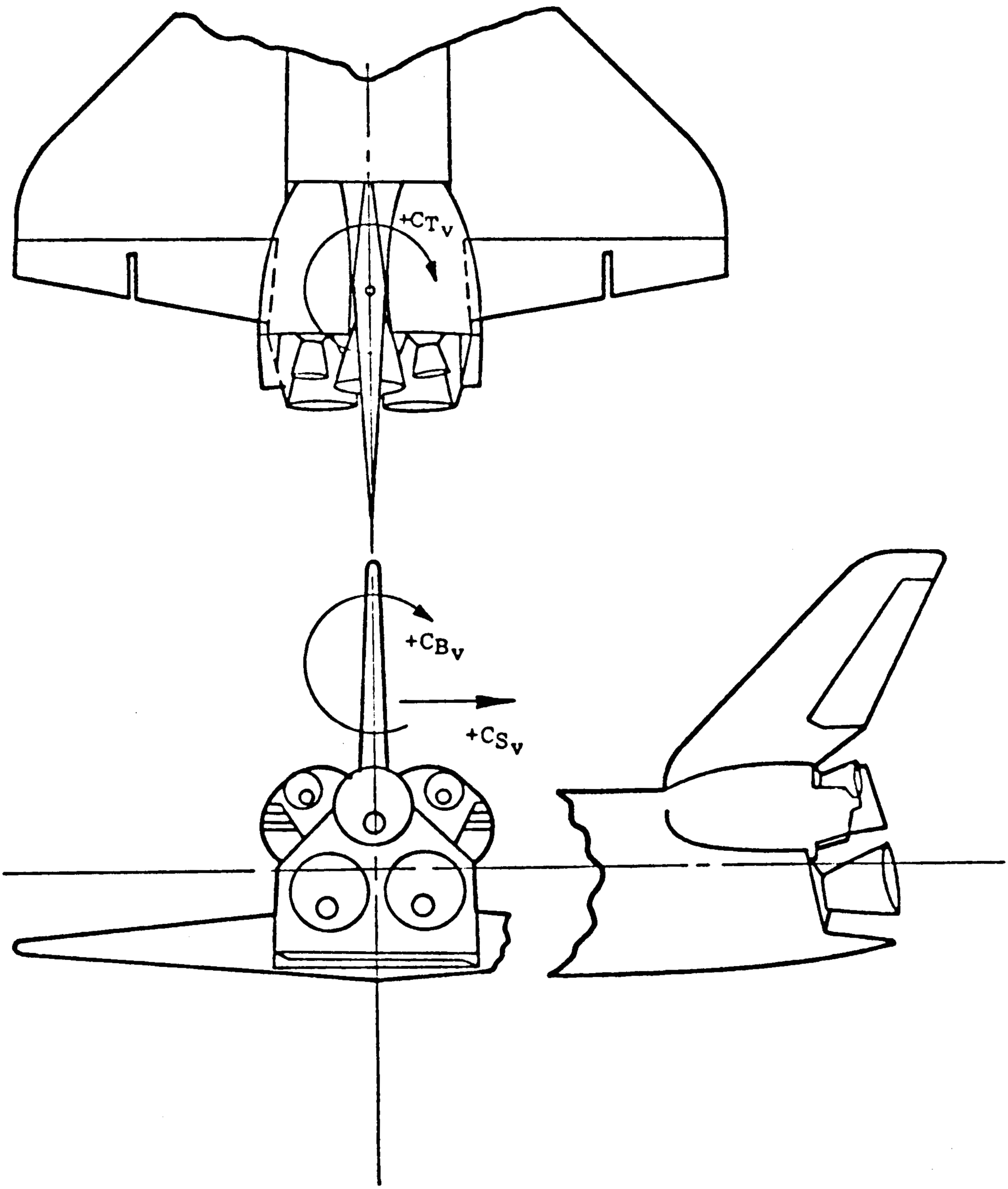
c. Main Balance Transfer Diagram
Figure 1. Continued.



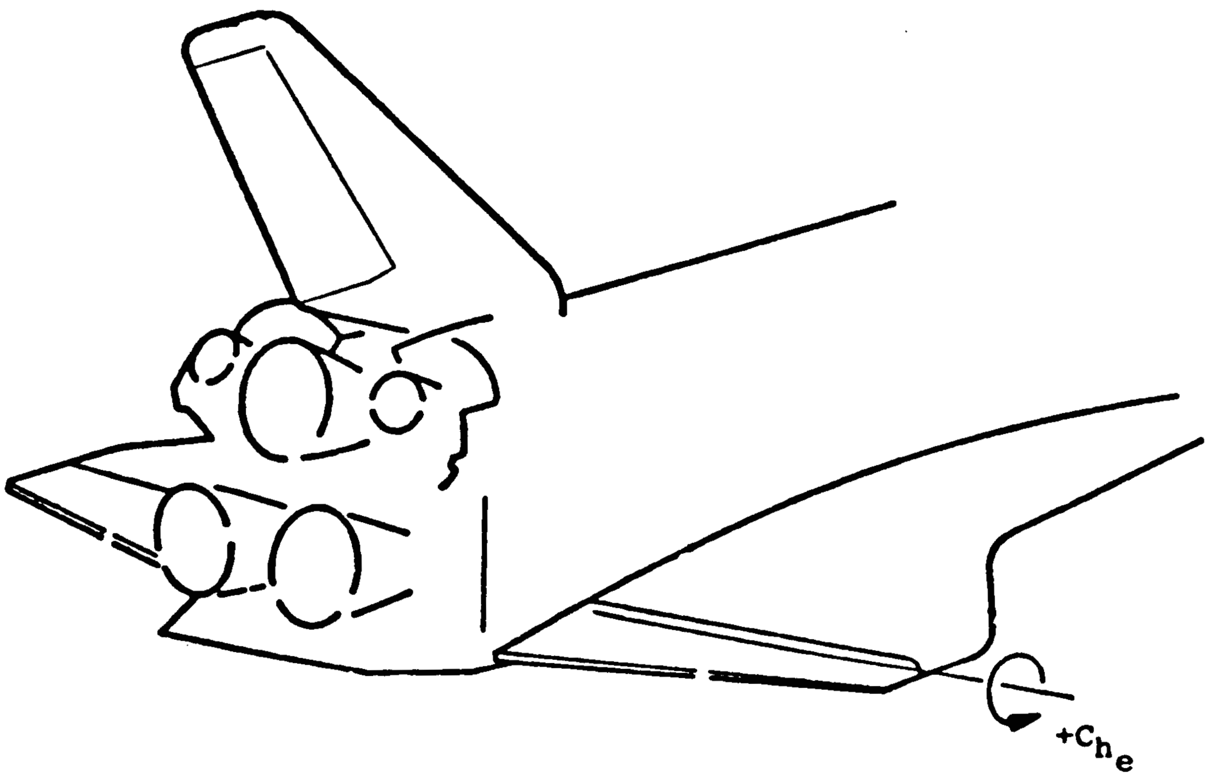
d. Wing Moment Reference Center
Figure 1. Continued



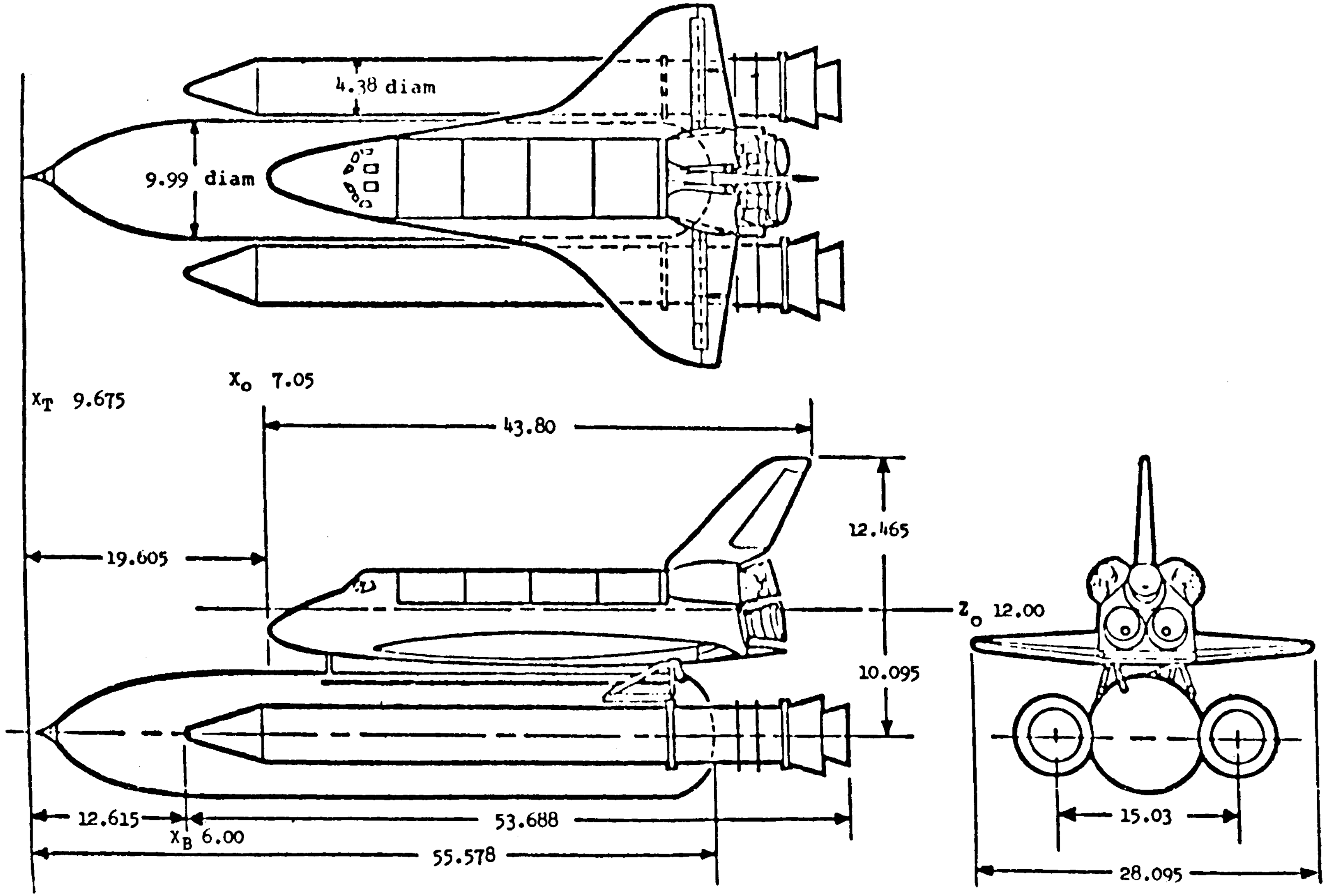
e. Vertical Stabilizer Balance Transfer Diagram
Figure 1. Continued.



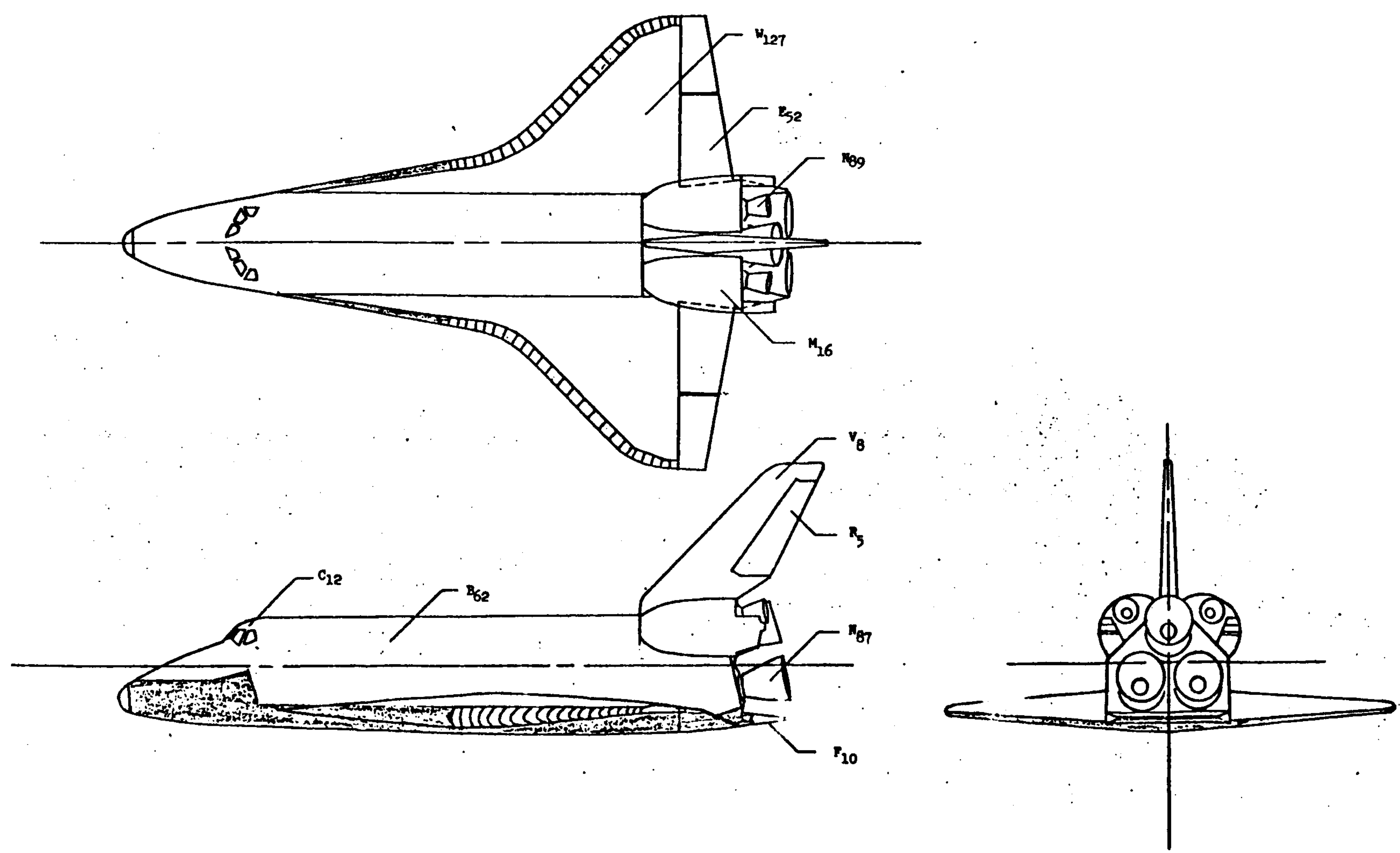
f. Definition of Vertical Stabilizer Coefficients
Figure 1. Continued.



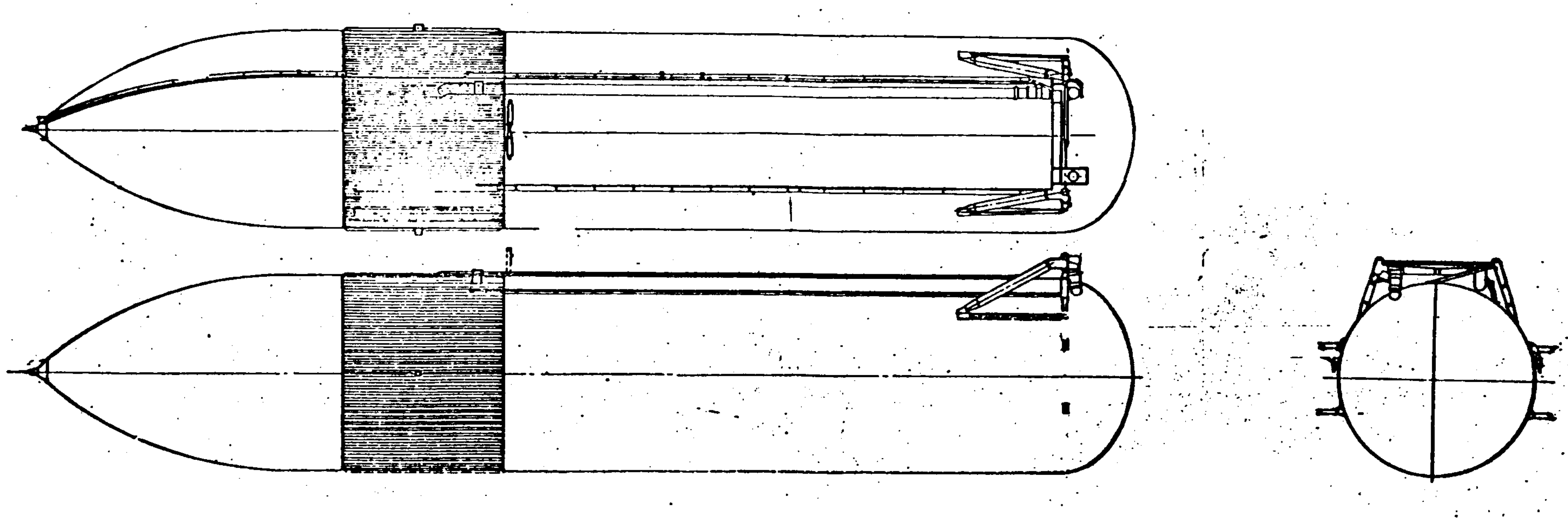
g. Definition of Elevon Hinge Moment Coefficients
Figure 1. Concluded.



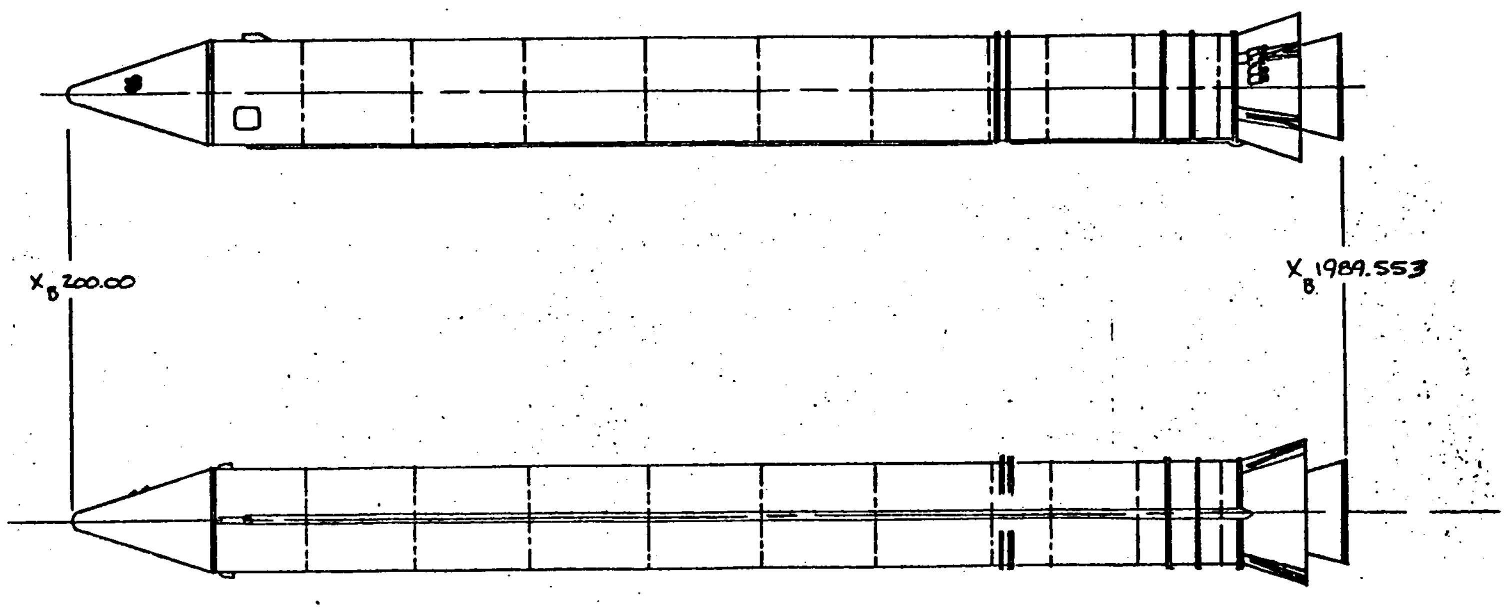
a. Major Model Component Dimensions
Figure 2. Model sketches.



b. 102 Orbiter
Figure 2. Continued.

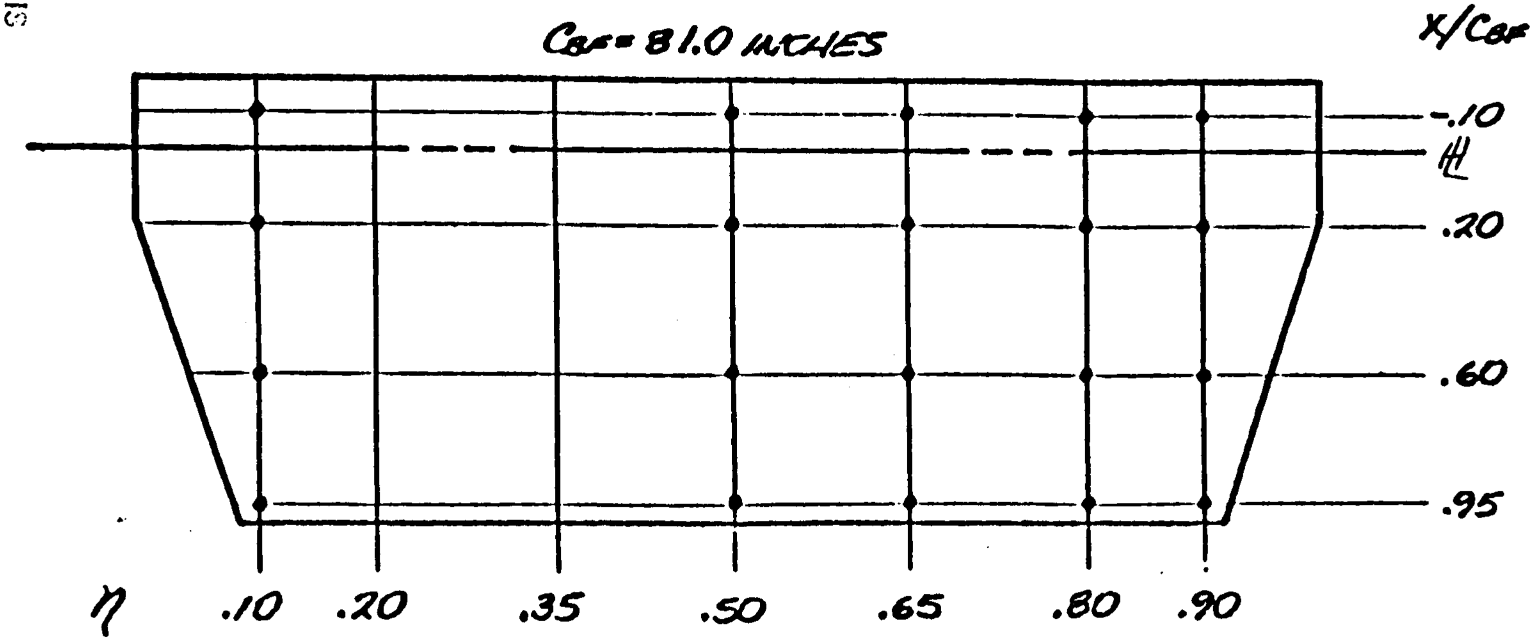


c. External Tank (T_{39})
Figure 2. Continued.



d. Solid Rocket Booster (S_{27})
Figure 2. Continued.

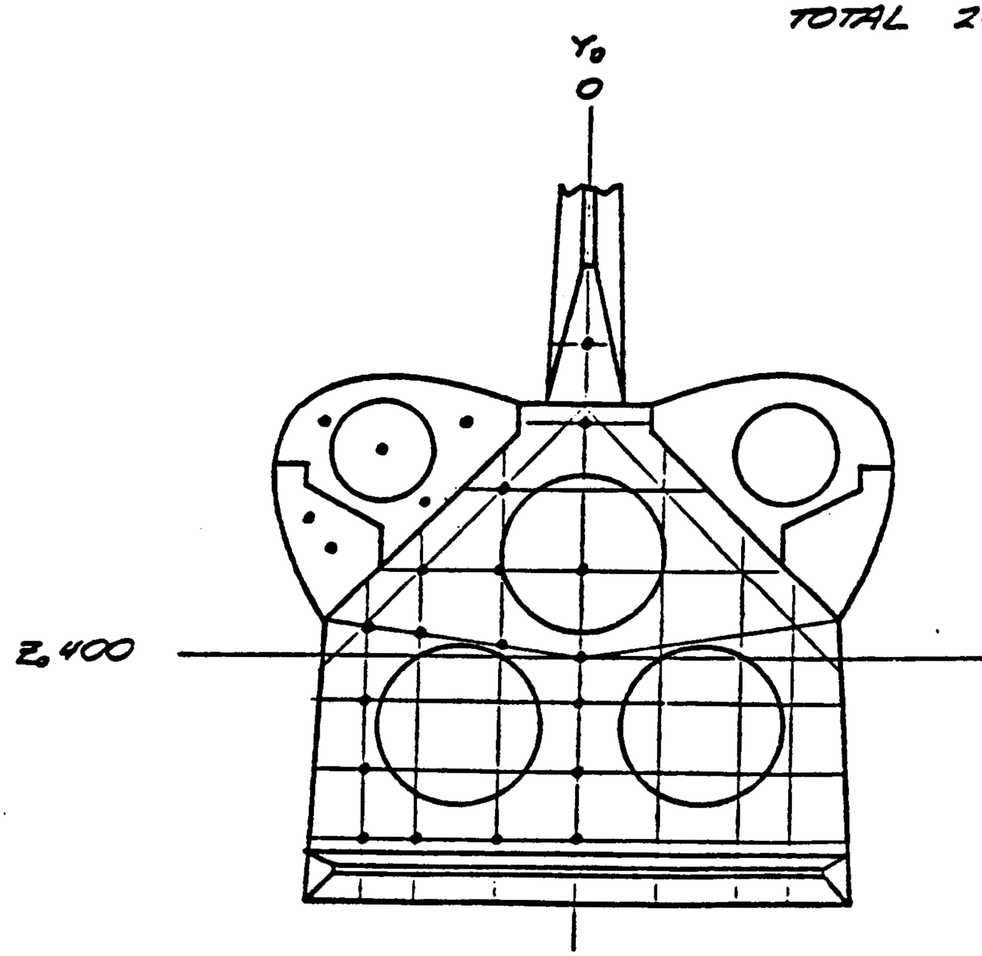
η	X/C_BF (BOT)				X/C_BF (TOP)			
	-.10	.20	.60	.95	-.10	.20	.60	.95
.10	401	402	403	404	405	406	407	408
.20								
.35								
.50	409	410	411	412	413	414	415	416
.65	417	418	419	420	421	422	423	424
.80	425	426	427	428	429	430	431	432
.90	433	434	435	436	437	438	439	440



e. Orbiter Body Flap Pressure Instrumentation
Figure 2. Continued.

TAP	Z_o	Y_o	TAP	Z_o	Y_o	TAP	Z_o	Y_o
301	532	0	311	302	-38	321	522	-103
302	505	0	312	439	-78	322	470	-96
303	443	0	313	410	-78	323	439	-107
304	400	0	314	302	-78	324	465	-130
305	376	0	315	414	-103			
306	340	0	316	376	-103			
307	302	0	317	340	-103			
308	478	-38	318	302	-103			
309	439	-38	319	514	-55			
310	405	-38	320	492	-58			

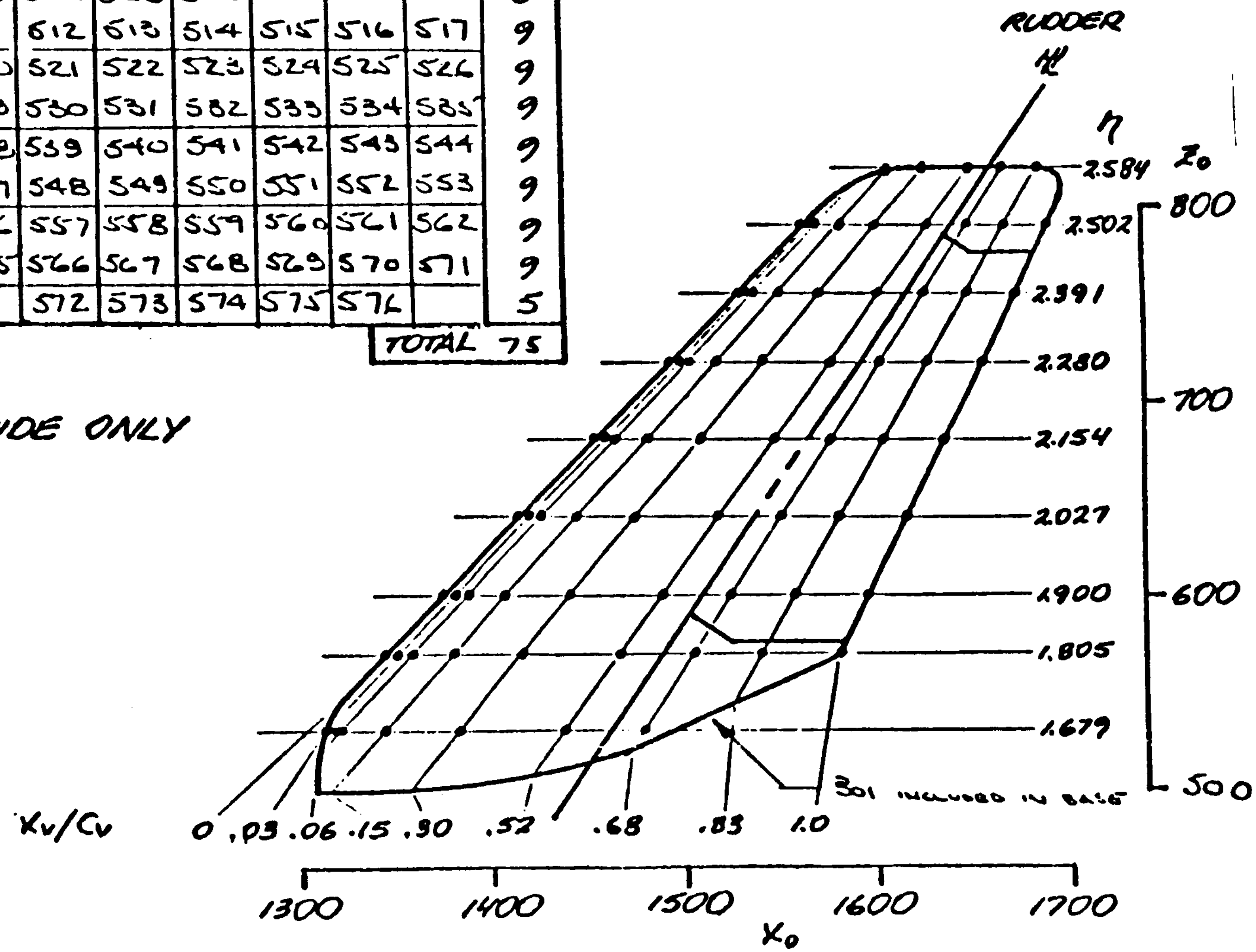
TOTAL 24



f. Orbiter Base Pressure Instrumentation
Figure 2. Continued.

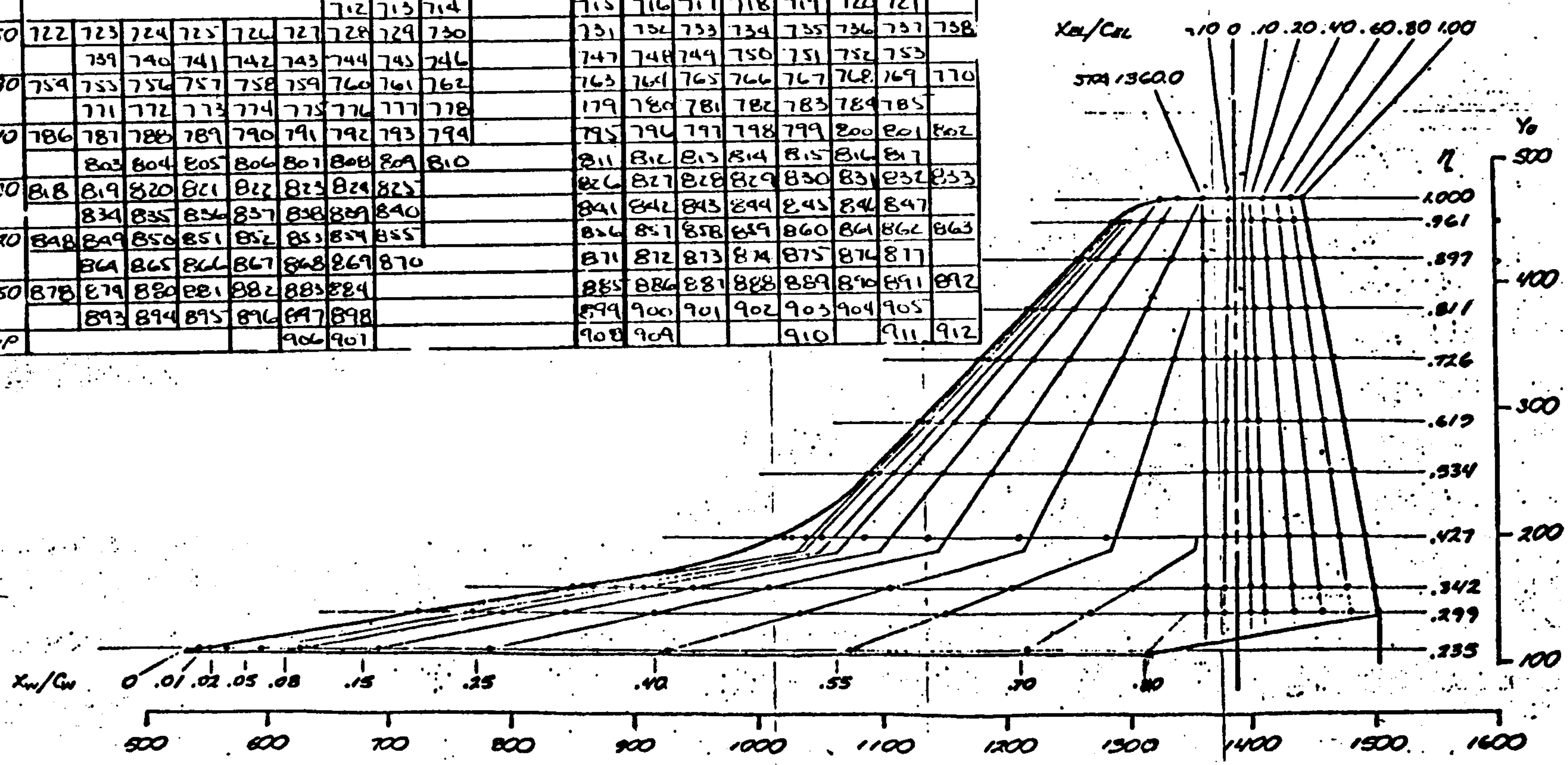
Z_o	η	X_r/C_v									Σ
		0	.03	.06	.15	.30	.52	.68	.83	1.0	
530		501	502	503	504	505	506	507			8
570		508	510	611	512	513	514	515	516	517	9
600		518	519	520	521	522	523	524	525	526	9
640		527	528	529	530	531	582	533	534	535	9
680		536	507	538	539	540	541	542	543	544	9
720		545	546	547	548	549	550	551	552	553	9
755		554	555	556	557	558	559	560	561	562	9
790		563	564	565	566	567	568	569	570	571	9
TIP					572	573	574	575	576		5
										TOTAL	75

LEFTHAND SIDE ONLY

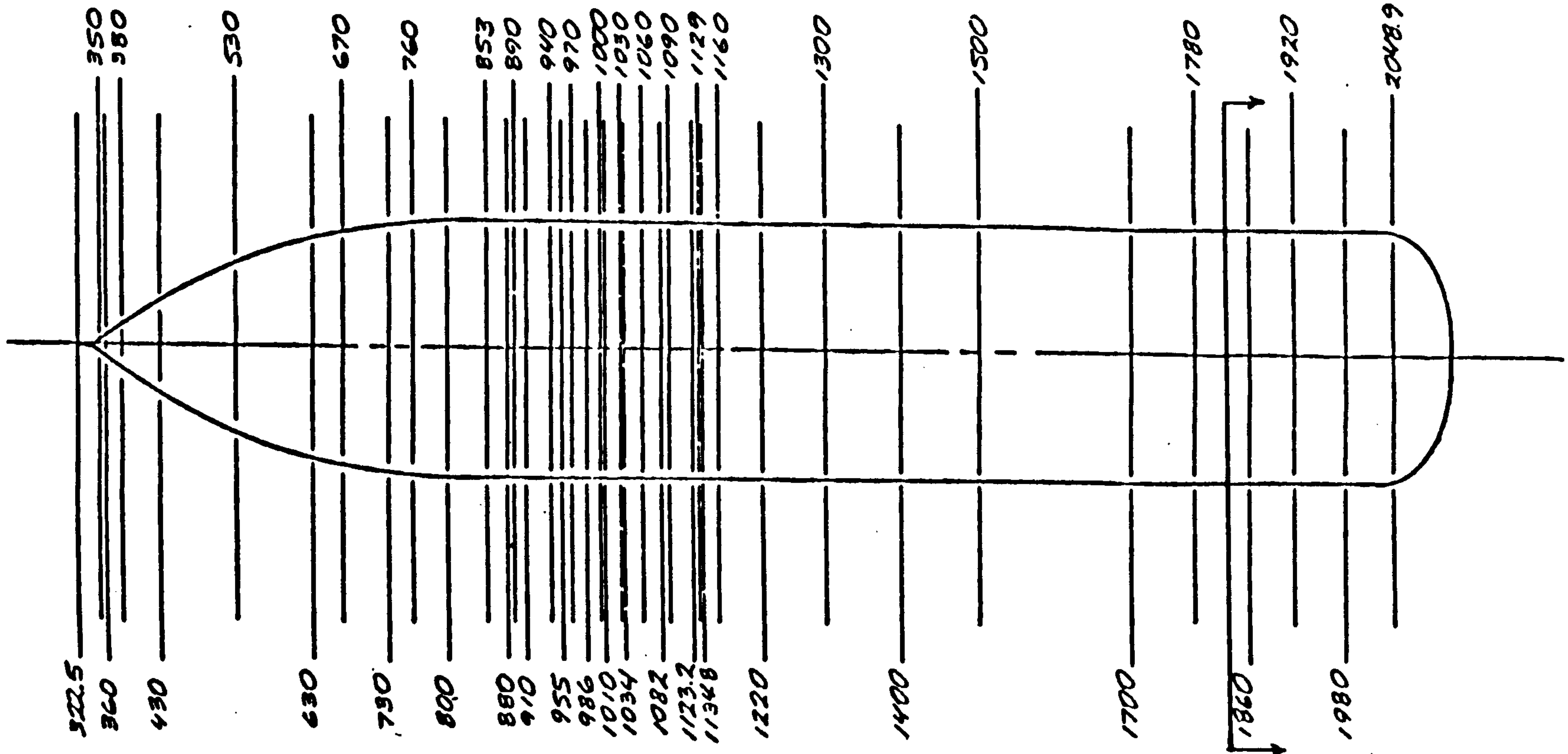


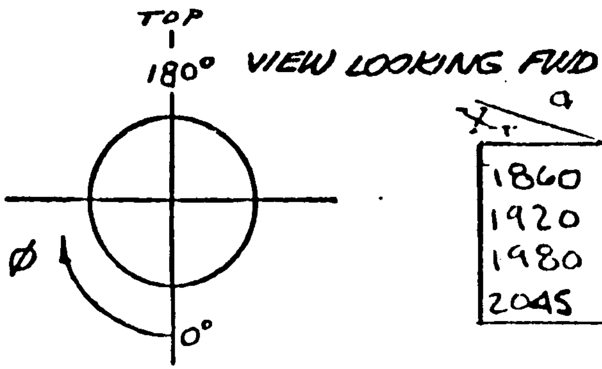
g. Orbiter Vertical Tail Pressure Instrumentation
Figure 2. Continued.

	η	Y_o	X_w/C_w											X_o	X_{el}/C_{el}						
			0	.01	.02	.05	.08	.15	.25	.40	.55	.70	.80	1360	-.10	.10	.20	.40	.60	.80	1.0
TOP	.235	110										610	611								
BOT												620	621								
TOP	.299	140									630	631		632	633	634	635	636	637	638	639
BOT											647	648		649	650	651	652	653	654	655	
TOP	.342	160								663	664	665		666	667	668	669	670	671	672	673
BOT										680	681	682		683	684	685	686	687	688	689	
TOP	.427	200							696	697	698			699	700	701	702	703	704	705	706
BOT									712	713	714			715	716	717	718	719	720	721	
TOP	.534	250	722	723	724	725	726	727	728	729	730			731	732	733	734	735	736	737	738
BOT				739	740	741	742	743	744	745	746			747	748	749	750	751	752	753	
TOP	.619	290	754	755	756	757	758	759	760	761	762			763	764	765	766	767	768	769	770
BOT				771	772	773	774	775	776	777	778			779	780	781	782	783	784	785	
TOP	.726	340	786	787	788	789	790	791	792	793	794			795	796	797	798	799	800	801	802
BOT				803	804	805	806	807	808	809	810			811	812	813	814	815	816	817	
TOP	.811	380	818	819	820	821	822	823	824	825				826	827	828	829	830	831	832	833
BOT				834	835	836	837	838	839	840				841	842	843	844	845	846	847	
TOP	.897	420	848	849	850	851	852	853	854	855				856	857	858	859	860	861	862	863
BOT				864	865	866	867	868	869	870				871	872	873	874	875	876	877	
TOP	.961	450	878	879	880	881	882	883	884					885	886	887	888	889	890	891	892
BOT				893	894	895	896	897	898					899	900	901	902	903	904	905	
	1.00	TIP						906	907					908	909			910		911	912



h. Orbiter Wing Pressure Instrumentation
Figure 2. Continued.

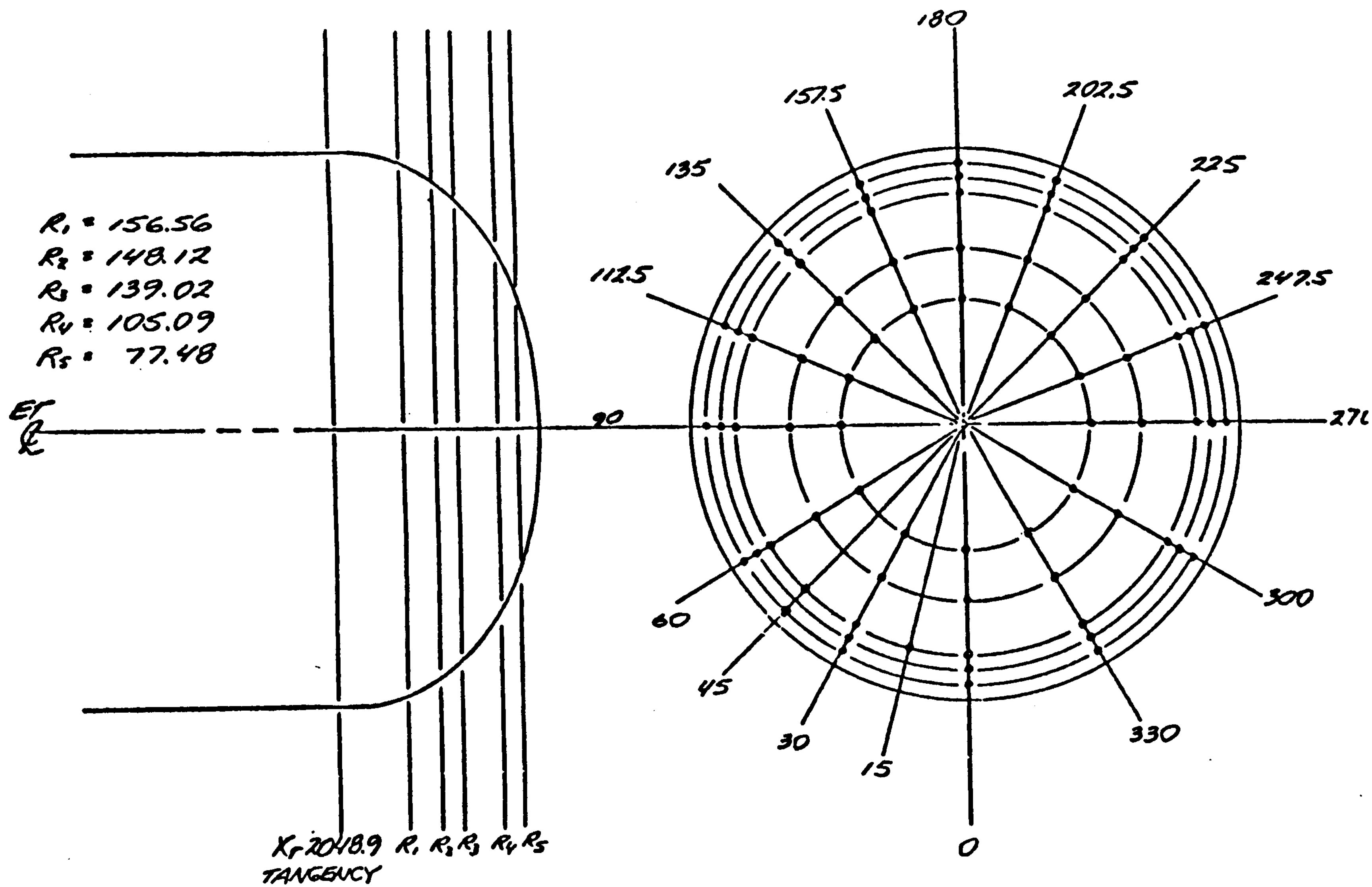




ET PRESSURE TAP ASSIGNMENT

X_T \ φ	0	30	60	90	112.5	135	157.5	180	225	247.5	270	300	330
1860	1374	1375	1376	1377	1378	1379	1380	1381	1382	1383	1384	1385	1386
1920	1387	1388	1389	1390	1391	1392	1393	1394	1395	1396	1397	1398	1399
1980	1400	1401	1402	1403	1404	1405	1406	1407	1408	1409	1410	1411	1412
2045	1413	1414	1415	1416	1417	1418	1419	1420	1421	1422	1423	1424	1425

i. External Tank Pressure Instrumentation
Figure 2. Continued.



Note: See Table V for Pressure Tap Number Assignments

j. External Tank Base Pressure Instrumentation
Figure 2. Continued.

• LH_2 TANK CABLE TRAY (16 TAPS)

TAPS # 1671 → 1682

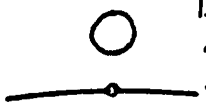
4 TAPS AS SHOWN FOR THE FOLLOWING STATIONS: 1820

LOCKING AFT

1884
1948
2008

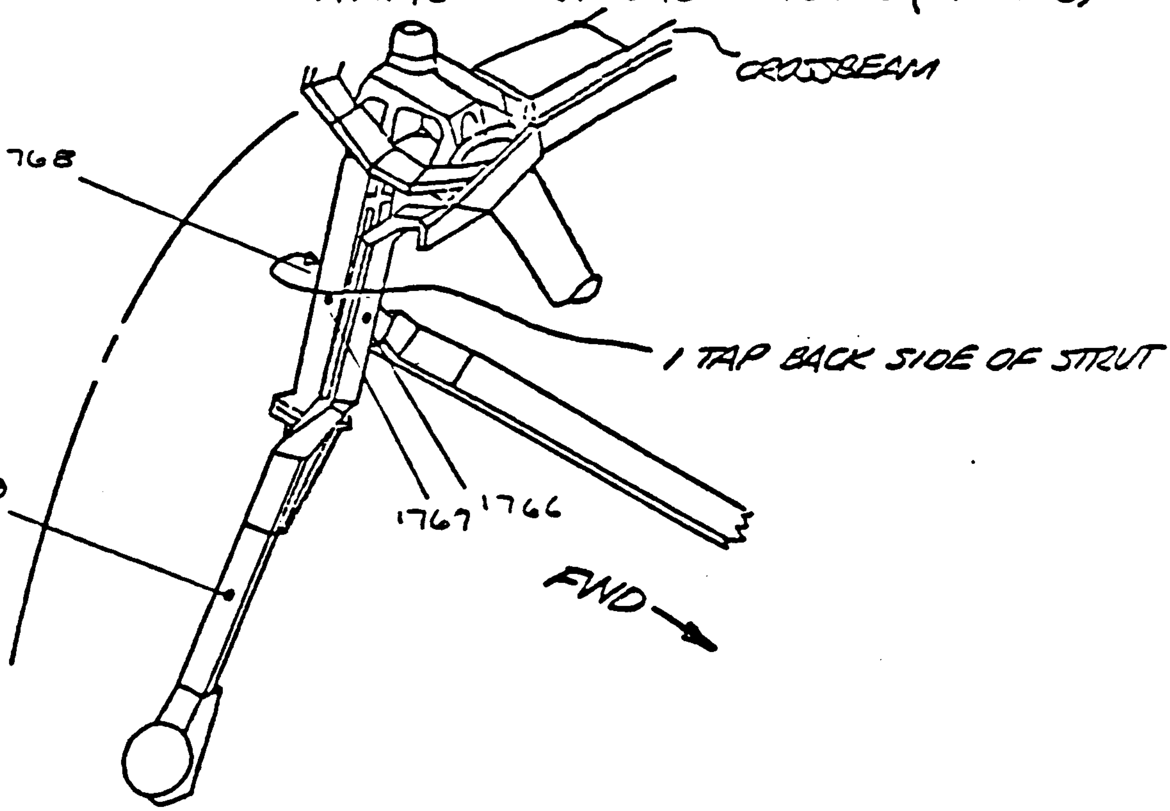
• GO_2 PRESSURE LINE (4 TAPS)

TAPS # 1721 → 1724



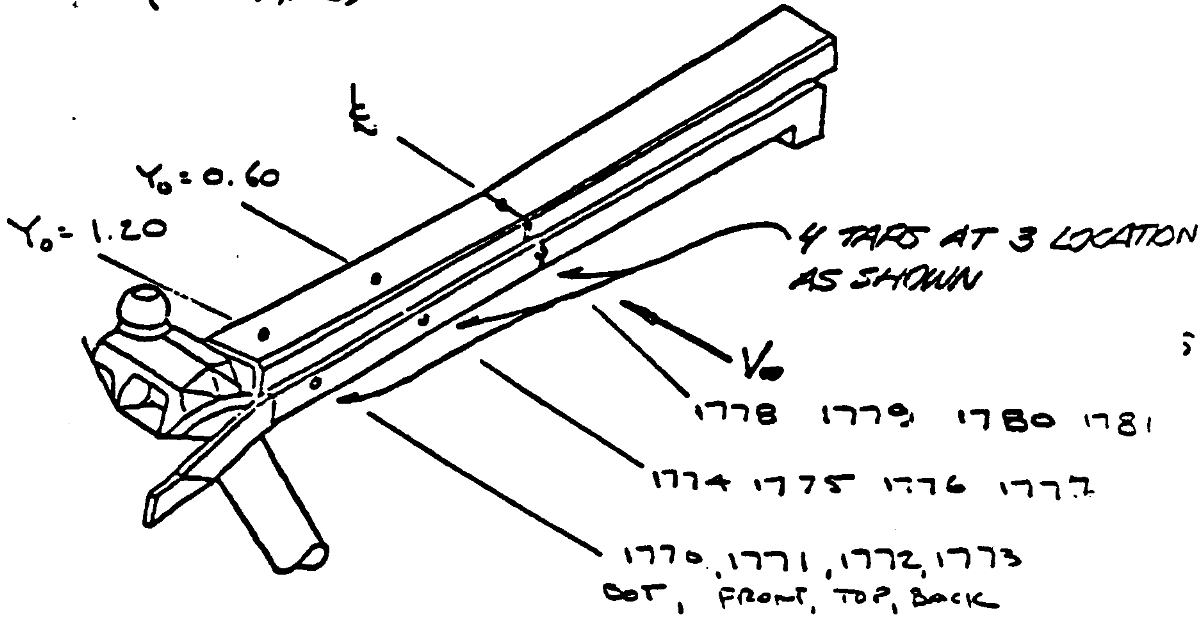
1 TAP AS SHOWN FOR THE FOLLOWING STATIONS: 1820
1884
1948
2008

• AFT ET ATTACHMENT CABLE TRAYS (4 TAPS)

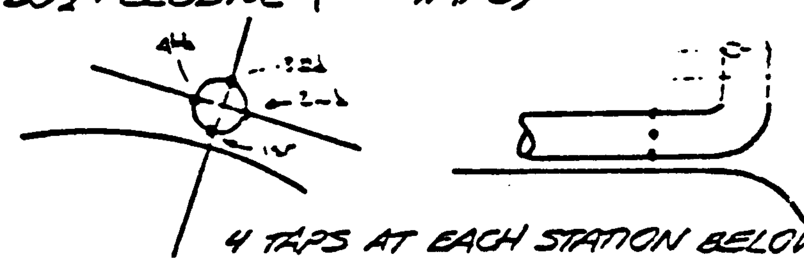


k. External Tank Protuberance Pressure Instrumentation
Figure 2. Continued.

• AFT ATTACH STRUCTURE CROSSBEAM (12 TAPS)



• LO_2 FEEDLINE (TAPS)



4 TAPS AT EACH STATION BELOW:

TAPS	1810 → 1821	1800 1900 2000

• GH_2 PRESSURE LINE (2 TAPS)

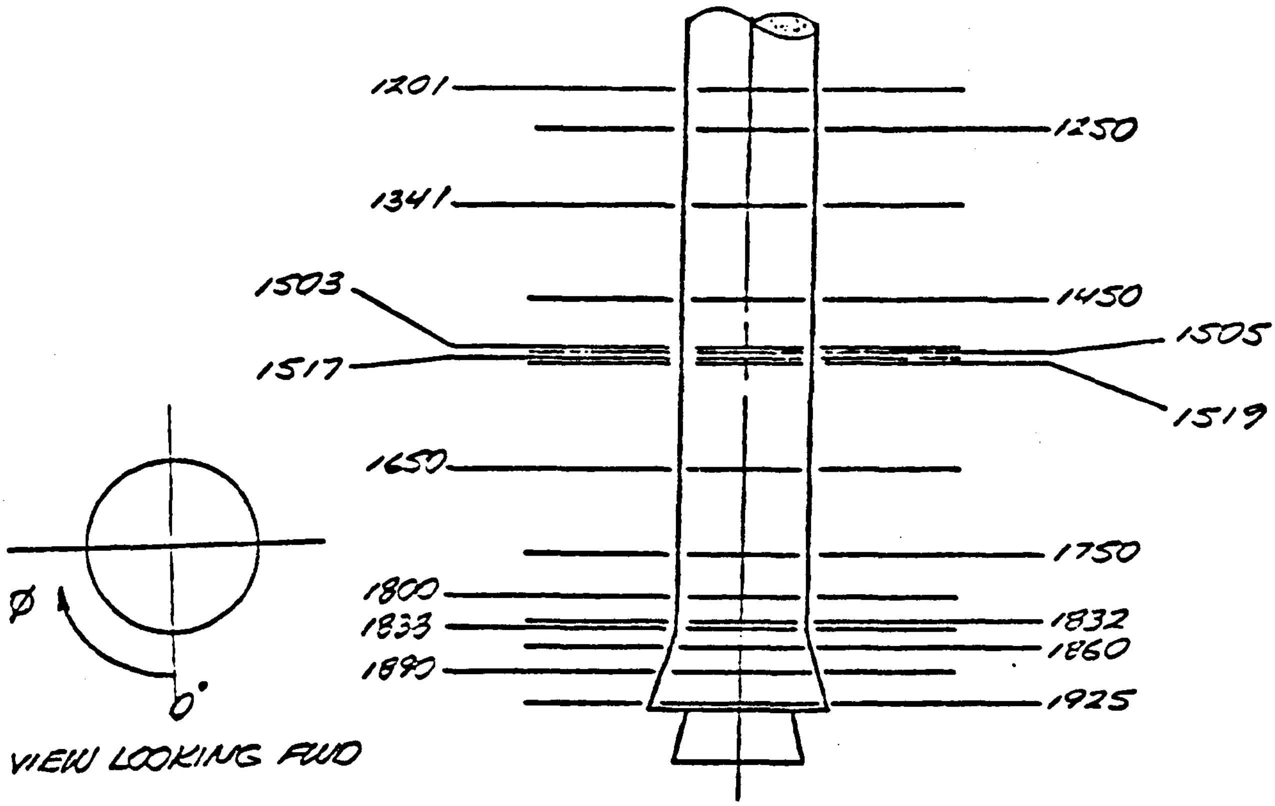
1836 → 1837
1 TAP AS SHOWN FOR THE FOLLOWING STATIONS: 1900, 2000

• LO_2 ANTIGEYSER LINE (3 TAPS)

1847 → 1849
1 TAP AS SHOWN FOR THE FOLLOWING STATIONS: 1800
1900
2000

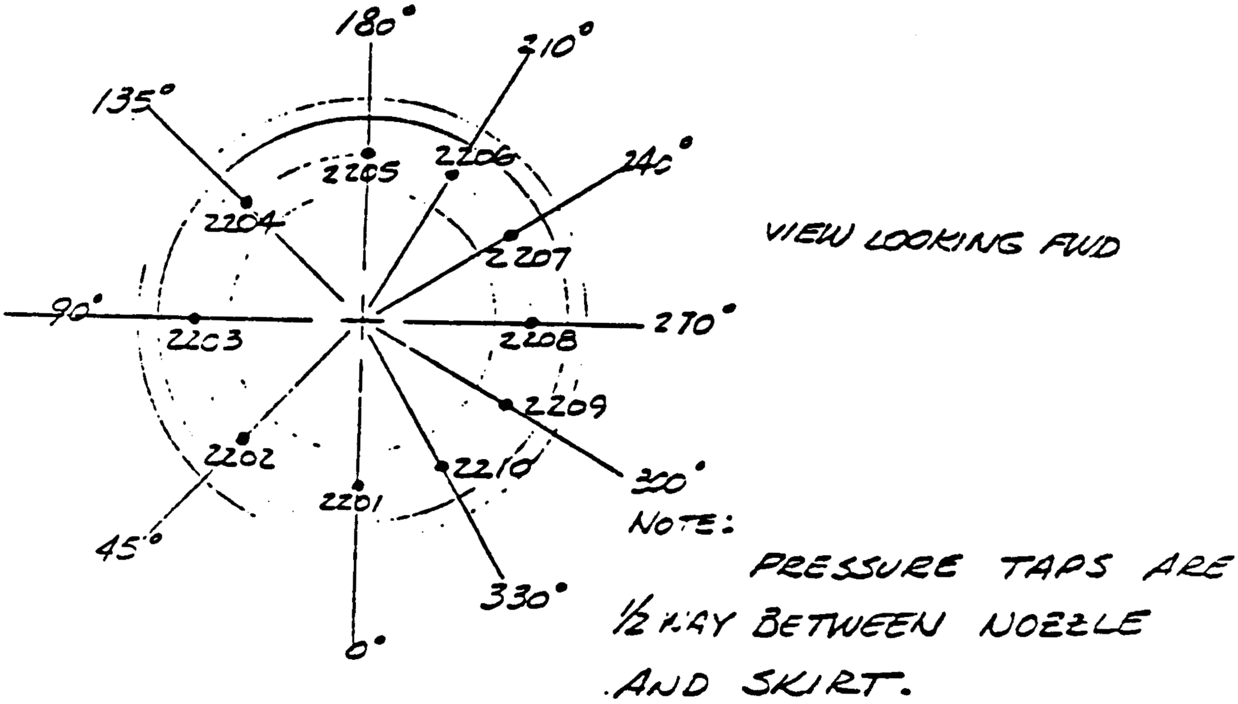
1. External Tank Protuberance Pressure Instrumentation
Figure 2. Continued.

STA \ Ø	0	45	86	90	94	135	180	225	247.5	270	292.5	315
1341	—	—	2078	—	2079	—	—	—	—	—	—	—
1450	2080	2081	—	—	—	2082	2083	2084	—	2085	—	2086
1503	2087	2088	2089	—	2090	2091	2092	2093	—	2094	—	2095
1505	2096	2097	—	—	—	2098	2099		—	2101	—	
1517	2103	2104	—	—	—	2105	2106		—	2108	—	
1519	—	—	—	—	2110	—	—	—	—	—	—	—
1650	2111	2112	2113	—	2114	2115	2116	2117	—	2118	—	2119
1750	2120	2121	—	—	—	2122	2123	2124	—	2125	—	2126
1800	2127	2128	2129	—	2130	2131	2132	2133	—	2134	—	2135
1832	2136	2137	—	—	—	2138	2139	2140	—	2141	—	2142
1838	2143	2144	—	—	—	2145	2146	2147	—	2148	—	2149
1860	2150	2151	—	2152	—	2153	2154	2155	3156	2157	2158	2159
1890	2160	2161	—	2162	—	2163	2164	2165	2166	2167	2168	2169
1925	2170	2171	—	2172	—	2173	2174	2175	2176	2177	2178	2179

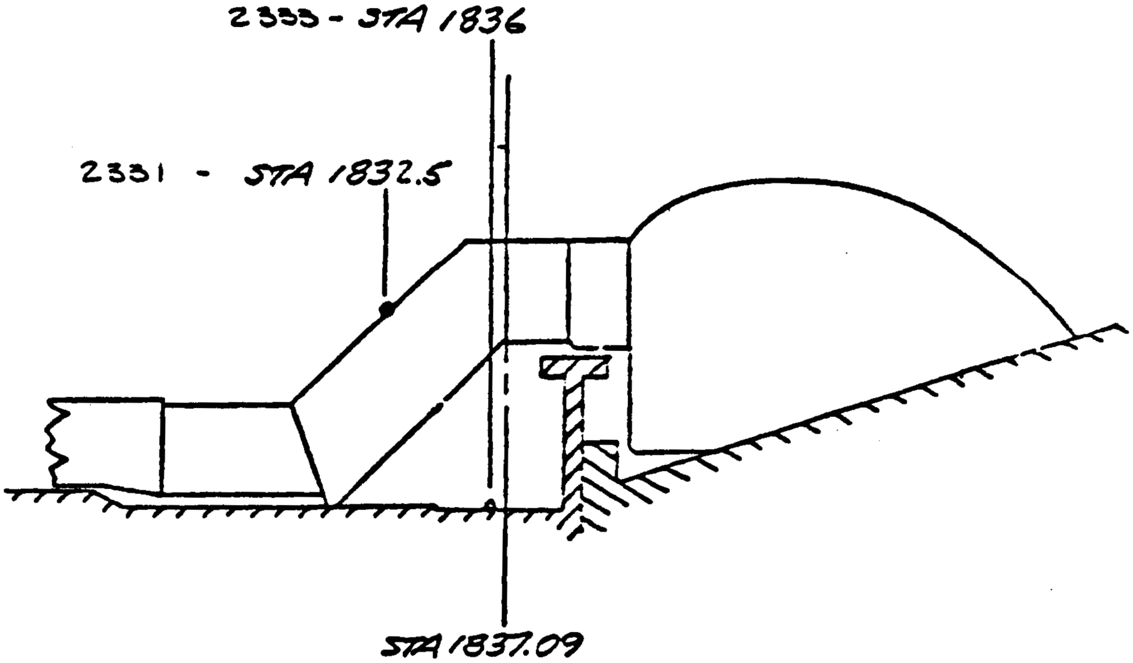


m. Solid Rocket Booster Pressure Instrumentation
Figure 2. Continued.

• BASE PRESSURE INSTRUMENTATION



• AFT FAIRING-SYSTEMS TUNNEL (2 TAPS)



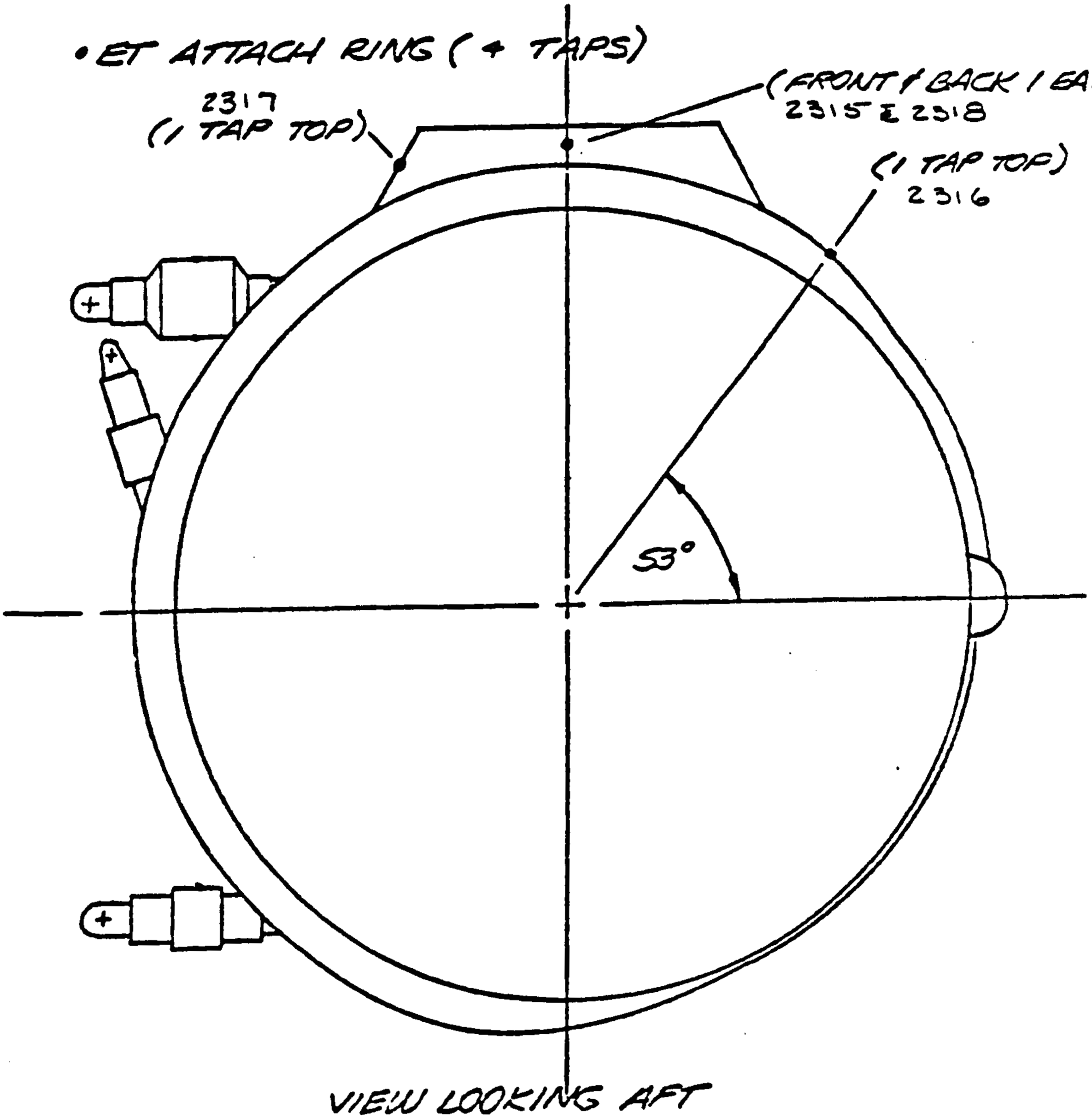
n. Solid Rocket Booster Base and Protuberance Pressure Instrumentation
Figure 2. Continued.

• CENTER SECTION-SYSTEMS TUNNEL (13 TAPS)

• 1 TAP LOCATED TOP CENTERLINE OF FAIRING AT THE FOLLOWING SRB STATIONS:

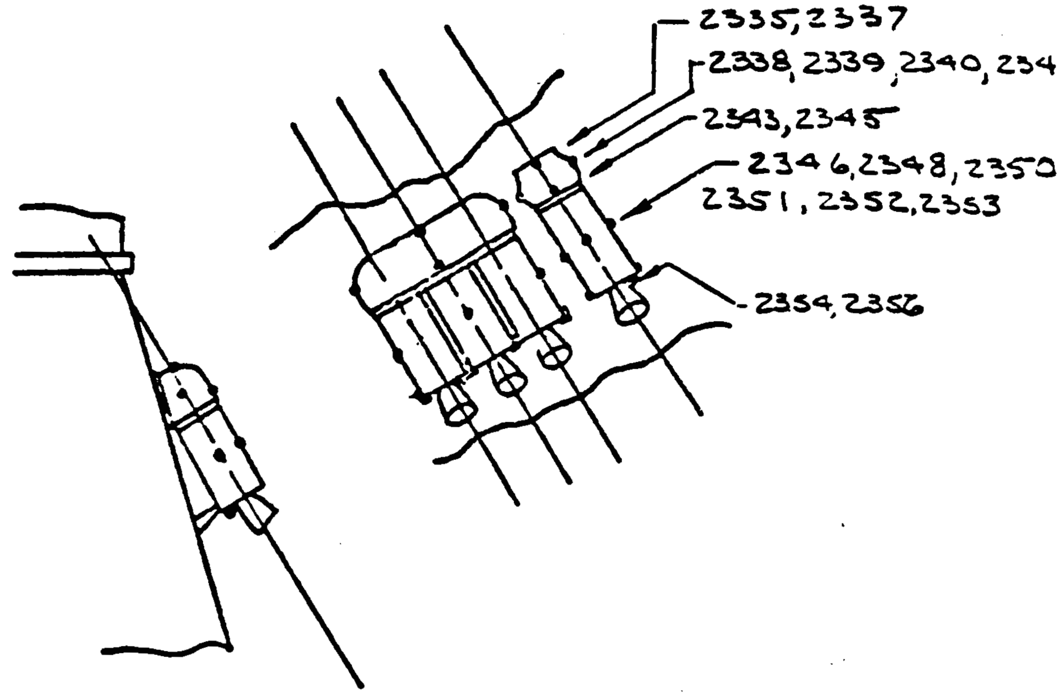
TAP NO.	X_B	TAP NO.	X_B	TAP NO.	X_B
2312	1201	2327	1591	2330	1800
2313	1341	2328	1650		
2314	1503	2329	1726		

• ET ATTACH RING (4 TAPS)

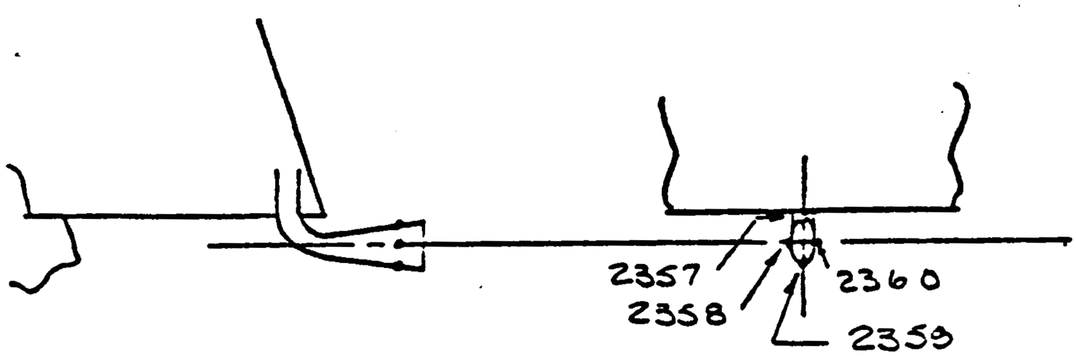


o. Solid Rocket Booster Protuberance Instrumentation
Figure 2. Continued.

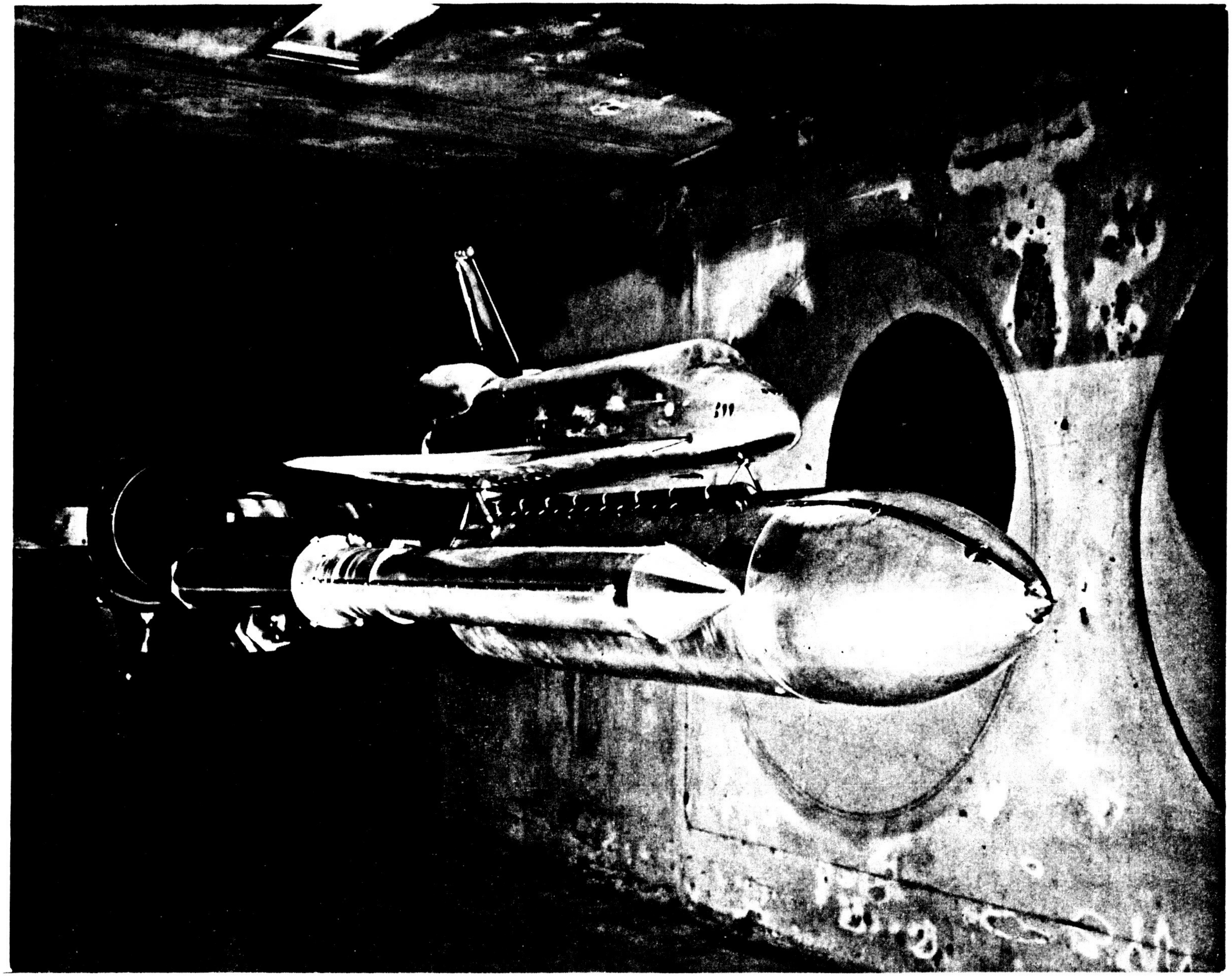
• SEPARATION MOTOR FAIRINGS (16. TAPS)



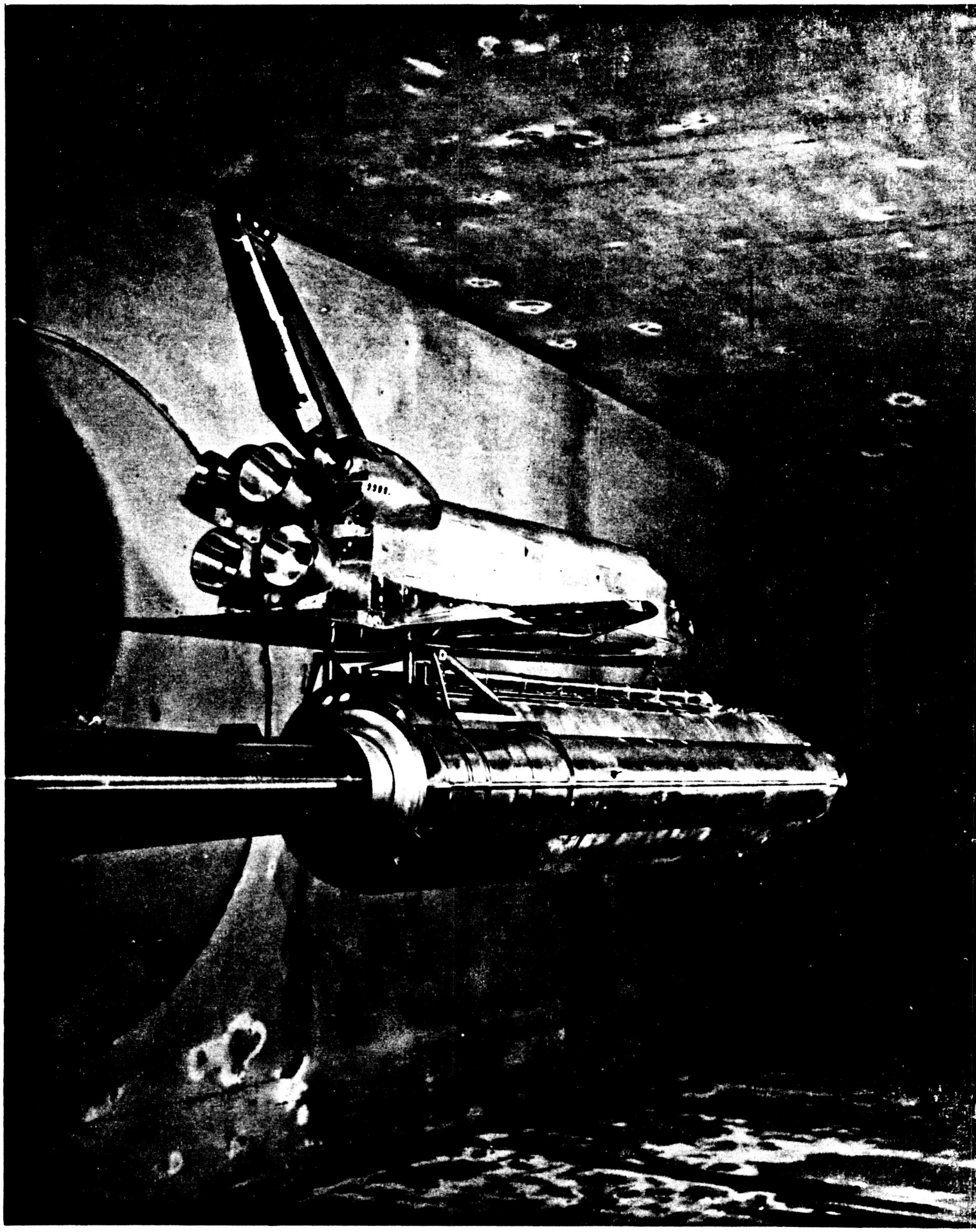
• TURBINE EXHAUST (4 TAPS). - TAPS ON ONE ONLY OF THE TWO EXHAUSTS - EITHER ONE



p. Solid Rocket Booster Protuberance Instrumentation
Figure 2. Concluded.



a. Three-Quarter Front View of Model 47ØTS
in the ARC 9x7 Foot UPWT
Figure 3. Model Installation Photographs



b. Three-Quarter Rear View of Model 47ØTS in the ARC 9x7 Foot UPWT
Figure 3. Concluded

APPENDIX

TABULATED SOURCE DATA